History of unmanned aerial vehicles

Unmanned aerial vehicles (**UAVs**) include both autonomous (capable of operating without human input) drones and remotely piloted vehicles (RPVs). A UAV is capable of controlled, sustained level flight and is powered by a jet, reciprocating, or electric engine.[1] In the twenty-first century, technology reached a point of sophistication that the UAV is now being given a greatly expanded role in many areas of aviation.

A BQM-74 Chukar III, turbojet-powered aerial target drone

A UAV differs from a cruise missile in that a UAV is intended to be recovered after its mission, while a cruise missile impacts its target. A military UAV may carry and fire munitions on board, while a cruise missile is a munition. Loitering munitions are a class of unmanned aircraft intermediate between them.

Early development

Austrian incendiary balloon attack on Venice

The earliest recorded use of an unmanned aerial vehicle for warfighting occurred in July 1849,[2][3] serving as a balloon carrier (the precursor to the aircraft carrier)[4] is the first offensive use of air power in naval aviation.[5][6][7] Austrian forces besieging Venice attempted to float some 200 incendiary balloons each carrying a 24- to 30-pound bomb that was to be dropped from the balloon with a time fuse over the besieged city. The balloons were launched mainly from land; however, some were also launched from the Austrian ship SMS *Vulcano*. The Austrians used smaller pilot balloons to determine the correct fuse settings. At least one bomb fell in the city; however, due to the wind changing after launch, most of the balloons missed their target, and some drifted back over Austrian lines and the launching ship *Vulcano*.[8][9][10]

World War I

The first pilotless aircraft were built during World War I. From a suggestion that A. M. Low's expertise in early television and radio technology be used to develop a remotely controlled pilotless aircraft to attack the Zeppelins[11][12] a remarkable succession of British drone weapons in 1917 and 1918 evolved. Designers from Sopwith Aviation and its contractor Rushton Proctor, de Havilland and the Royal Aircraft Factory all became involved. They were all designed to use Low's radio control system developed at the Royal Flying Corps secret Experimental Works at Feltham. Of these Low confirmed that Geoffrey de Havilland's monoplane was the one that flew under control on 21 March 1917.[13] Low is known as "'father of radio guidance systems" and in 1976 Low was inducted into the International Space Hall of Fame. Alternatively, John Taylor suggested Low was the 'Father of the Remotely Piloted Vehicle'.[14]

Soon after, on September 12, the Hewitt-Sperry Automatic Airplane, otherwise known as the "flying bomb" made its first flight, demonstrating the concept of an unmanned aircraft. They were intended for use as "aerial torpedoes," an early version of today's cruise missiles. Control was achieved using gyroscopes developed by Elmer Sperry of the Sperry Gyroscope Company.[15]

Later, in November 1917, the Automatic Airplane was flown for representatives of the US Army. This led the army to commission a project to build an "aerial torpedo", resulting in the Kettering Bug which first flew in 1918. While the Bug's revolutionary technology was successful, it was not in time to fight in the war, which ended before it could be fully developed and deployed.[16]

Interwar period

Winston Churchill, David Margesson and others wait to watch the launch of a de Havilland Queen Bee target drone, 6 June 1941

After World War I, three Standard E-1s were converted to drones.[17] The Larynx was an early cruise missile in the form of a small monoplane aircraft that could be launched from a warship and flown under autopilot; the Royal Navy tested it between 1927 and 1929. The early successes of pilotless aircraft led to the development of radio controlled pilotless target-aircraft in Britain

and the US in the 1930s. In 1931 the British developed the Fairey Queen radio-controlled target from the Fairey IIIF floatplane, building a small batch of three, and in 1935 followed up this experiment by producing larger numbers of another RC target, the "DH.82B Queen Bee", derived from the de Havilland Tiger Moth biplane trainer. The name of "Queen Bee" allegedly led to the use of the term "drone" for pilotless aircraft,[18] particularly when they are radio-controlled. During this period, the U.S. Navy, continuing work that reached back to 1917, also experimented with radio-controlled aircraft. In 1936 the head of US Navy research group used the term "DRONE" to designate radio-controlled aerial targets.[19][20] From 1929 Hungarian scientist Kálmán Tihanyi worked on television guidance for defense applications, building prototypes of a camera for remotely-guided aircraft in London for the British Air Ministry, and later adapting it for the Italian Navy.[21][22] In 1929, Tihanyi invented the first infrared-sensitive (night-vision) electronic television-camera for anti-aircraft defense in Britain.[23][24] The solutions of the technology that Tihanyi depicted in his 1929 patent became so influential that American UAV-producing companies still used many of its solutions even half a century later, until the mid-1980s.[25]

Subsequent British "drones" included the Airspeed Queen Wasp, the Miles Queen Martinet, and the US-supplied Curtiss Queen Seamew. After WW II these would be replaced by the jet-powered Anglo-Australian GAF Jindivik.

The Soviets tested pilotless munitions-delivery in 1935-1939.[26]

World War II

A Radioplane OQ-3 and its launcher, Wright Field, October 1945

A US Navy OQ-2 shot down by the USS *Makin Island* during a gunnery exercise off Wakanoura, Japan (October 1945)

Reginald Denny and the Radioplane

The first large-scale production, purpose-built drone was the product of Reginald Denny. He served with the British Royal Flying Corps during World War I, and after the war, in 1919, he returned to the United States to resume his career in Hollywood. Denny was a successful leading man and between acting jobs, he pursued his interest in radio control model aircraft in the 1930s opening a shop.[27]

The shop evolved into the "Radioplane Company". Denny believed that low-cost RC aircraft would be very useful for training anti-aircraft gunners, and in 1935 he demonstrated a prototype target drone, the RP-1, to the US Army. Denny then bought a design from Walter Righter in 1938 and began marketing it to hobbyists as the "Dennymite", and demonstrated it to the Army as the RP-2, and after modifications as the RP-3 and RP-4 in 1939. In 1940, Denny and his partners won an Army contract for their radio controlled RP-4, which became the Radioplane OQ-2. They manufactured nearly fifteen thousand drones for the Army during World War II.

The true inventor of a radio-controlled aircraft that could fly out of sight was Edward M. Sorensen as evidenced by his US patents. His invention was the first to be able to know from a ground terminal what the airplane was doing, such as climbing, altitude, banking, direction, rpm and other instrumentation. Without these patents the early radio-controlled aircraft could only operate within visual sight of the ground pilot.[28]

Aerial torpedoes

The US Navy began experimenting with radio-controlled aircraft during the 1930s as well, resulting in the Curtiss N2C-2 drone in 1937. The N2C-2 was remotely controlled from another aircraft, called a TG-2. N2C-2 anti-aircraft target drones were in service by 1938.[29]

The US Army Air Forces (USAAF) adopted the N2C-2 concept in 1939.[29] Obsolescent aircraft were put into service as "A-series" anti-aircraft target drones. Since the "A" code would be also

used for "Attack" aircraft, later "full-sized" targets would be given the "PQ" designation. USAAF acquired hundreds of Culver "PQ-8" target drones, which were radio-controlled versions of the Culver Cadet two-seat light civil aircraft, and thousands of the improved Culver PQ-14 Cadet derivative of the PQ-8. The US also used RC aircraft, including modified B-17 Flying Fortress and B-24 Liberator heavy bombers in Aphrodite and Anvil operations in combat on a small scale during World War II as very large aerial torpedoes, though with no great success and the loss of aircrew including Joseph P. Kennedy Jr.[30]

The "TDN-1" was an unmanned aerial vehicle that was developed for use in 1940. The TDN was capable of delivering a 1,000-pound bomb but never saw operational duty.

The Naval Aircraft Factory assault drone "Project Fox" installed an RCA television camera in the drone and a six-inch television screen in the TG-2 control aircraft in 1941.[29] In April 1942 the assault drone successfully delivered a demonstration torpedo attack on a US destroyer at a range of 20 miles from the TG-2 control aircraft.[29] Another assault drone was successfully crashed into a target moving at eight knots.[29] The Navy Bureau of Aeronautics then proposed a television-assisted remote control assault drone program of 162 control planes and 1,000 assault drones.[29] Disagreements arose within the Navy concerning the relative advantages of the proposed program for full-scale combat implementation versus a small-scale combat test with minimum aircraft resource expenditure which might reveal the concept to the enemy and allow development of countermeasures prior to full production.[29] Assault drones remained an unproven concept in the minds of military planners through major allied advances of 1944.[29] Utilization was limited to a 4-drone attack on a beached Japanese merchant ship in the Russell Islands at the end of July followed by expenditure of 46 drones in the northern Solomon Islands.[29] Two hits and two near-misses were scored on the stationary ship.[29] Several of the later drones failed to reach their targets, but most were effective.[29]

Pulsejets

The V-1 flying bomb was the first cruise missile ever built.[31] It was built in the Peenemünde Army Research Center and first tested in 1942. The V-1 was intended to target London and was massively fired, achieving more than one hundred launches a day. The V-1 was launched from a rail system to achieve the speed needed to operate its pulsejet engine and would achieve a 250 kilometers radius, at one point flying at 640 km/h.

McDonnell built a pulsejet-powered target, the TD2D-1 Katydid, later the KDD-1 and then KDH-1. It was an air-launched cigar-shaped machine with a straight mid-mounted wing, and a vee tail straddling the pulsejet engine. The Katydid was developed in mid-war and a small number were put into service with the US Navy.[32]

After the war, the Navy obtained small numbers of another pulsejet-powered target, the Curtiss KD2C Skeet series. It was another cigar-shaped machine, with the pulsejet in the fuselage and intake in the nose. It featured straight, low-mounted wings with tip tanks, and a triple-fin tail.

Balloons

Japan launched long distance attacks on the US Mainland using their Fu-Go unmanned balloons. They used the high-altitude jet stream and a novel ballast system to reach the northwestern US. Though intended to cause forest fires and widespread panic, their impact was not significant.

Cold War

Target drone evolution

In the post-World War II period, Radioplane followed up the success of the OQ-2 target drone with another very successful series of piston-powered target drones, what would become known as the Basic Training Target (BTT) family (the BTT designation wasn't created until the 1980s, but is used here as a convenient way to resolve the tangle of designations), including the OQ-19/KD2R Quail and the MQM-33/MQM-36 Shelduck. The BTTs remained in service for the rest of the 20th century. The first target drone converted to the battlefield unmanned aerial photo reconnaissance mission was a version of the MQM-33 conversion for the US Army in the mid-1950s designated the RP-71,[33] later re-designated the MQM-57 Falconer.

The US military acquired a number of other drones similar in many ways to the Radioplane drones. The Globe company built a series of targets, beginning with the piston-powered KDG Snipe of 1946, which evolved through the KD2G and KD5G pulsejet-powered targets and the KD3G and KD4G piston-powered targets, to the KD6G series of piston-powered targets. The KD6G series appears to have been the only one of the Globe targets to be built in substantial numbers. It was similar in size and configuration to the BTT series, but had a twin-fin tail. It was redesignated "MQM-40" in the early 1960s, by which time it was generally out of service.

The use of drones as decoys goes back to at least the 1950s, with the Northrop Crossbow tested in such a role. The first operational decoy drone was the McDonnell Douglas "ADM-20 Quail", which was carried by Boeing B-52 Stratofortress bombers to help them penetrate defended airspace.

By the late 1950s combat aircraft were capable of Mach 2, and so faster targets had to be developed to keep pace. Northrop designed a turbojet-powered Mach 2 target in the late 1950s, originally designated the Q-4 but later given the designation of AQM-35. In production form, it

was a slender dart with wedge-shaped stubby wings, swept conventional tail assembly, and a General Electric J85 turbojet engine, like that used on the Northrop F-5 fighter.

Nuclear tests

In 1946, eight B-17 Flying Fortresses were transformed by American airmen into drones for collecting radioactive data. They were controlled at takeoff and landing from a transmitter on a jeep, and during flight by a transmitter on another B-17. They were used on Bikini Atoll (Operation Crossroads) to gather samples from inside the radioactive cloud. During test Baker, two drones were flown directly above the explosion; when the shock wave reached them, both gained height, and the lowest was damaged. The U.S. Navy conducted similar tests with Grumman F6F Hellcat drones. The B-17 drones were employed in a similar manner in Operation Sandstone in 1947, and in Operation Greenhouse in 1951. In this latter test, also several Lockheed P-80 Shooting Star jets were used, modified into drones by Sperry Corporation; however, the complex system resulted in a very high accident rate. One of the B-17 drones, tail number 44-83525, is currently under restoration at Davis–Monthan Air Force Base.

Reconnaissance platforms

In the late 1950s, along with the Falconer, the US Army acquired another reconnaissance drone, the Aerojet-General SD-2 Overseer. It had a similar configuration to the Falconer, but featured a vee tail and was about twice as heavy.

The success of drones as targets led to their use for other missions. The well-proven Ryan Firebee was a good platform for such experiments, and tests to evaluate it for the reconnaissance mission proved highly successful. A series of reconnaissance drones derived from the Firebee, the Ryan Model 147 Lightning Bug series, were used by the US to spy on North Vietnam, Communist China, and North Korea in the 1960s and early 1970s.

The Lightning Bugs were not the only long-range reconnaissance drones developed in the 1960s. The US developed other, more specialized reconnaissance drones: the Ryan "Model 154", the Ryan and Boeing "Compass Copes", and the Lockheed D-21, all of which were more or less cloaked in secrecy.[34]

Soviet Union projects

The USSR also developed a number of reconnaissance drones, though since many programs the Soviets pursued were cloaked in secrecy, details of these aircraft are unclear and contradictory.

Yakolev Pchela-1K on Stroy-P launcher

Known drone systems planned or developed by the former Soviet Union include (in alphabetical order):

- Lavochkin La-17
- Tupolev Tu-123
- Tupolev Tu-141
- Tupolev Tu-143
- Tupolev Voron
- Yakovlev Pchela

Vietnam War: Reconnaissance drones

By late 1959, the only spy plane available to the US was the U-2. Spy satellites were another year and half away, and the SR-71 Blackbird was still on the drawing board.[35] In such a climate, concerns appeared about the negative publicity from the foreseen capture of US airmen on the communist territory. Pilots' fears were realized in May 1960, when U-2 pilot Francis Gary Powers was shot down over the USSR.[35] Not surprisingly, work intensified on an unmanned drone which would be capable of penetrating deep into enemy territory, and return with precise military intelligence. Within three months of the downing of the U-2, the highly classified UAV (called RPV back then) program was born, under the code name of *Red Wagon*.[35]

Just after the incident involving the US Navy destroyers USS *Maddox* (DD-731) and USS *Turner Joy* (DD-951), and even before it escalated into the presidential "Tonkin Gulf Resolution" and war with North Vietnam, the USAF had issued an immediate order for the UAV units to deploy immediately for Southeast Asia on any available C-130s or C-133s.[36] The first birds (drones) would be Ryan 147Bs (AQM-34s) piggy-backed on C-130s, after completing their missions they would be parachuted for recovery near Taiwan.[37]

USAF drones (UAVs) of the Strategic Air Command deployed to the Republic of South Vietnam (RVN) as the 4025th Strategic Reconnaissance Squadron, 4080th Strategic Reconnaissance Wing in 1964. In 1966 the unit was redesignated as the 350th Strategic Reconnaissance Squadron, 100th Strategic Reconnaissance Wing.[38]

The Squadron operated Ryan Firebees, launching them from modified DC-130A Hercules transport aircraft, normally two drones under each wing, each Hercules carrying 4 drones total. The UAVs deployed parachutes upon completing their missions and were usually recovered by helicopters which were tasked for those missions.[39]

The North Vietnamese Air Force utilized U.S. drone flights to practice their aerial combat skills, and although claiming several successful interceptions, only 6 are known to have been shot down by NVAF MiGs.[40][41] But there was a draw back for chasing drones; one North Vietnamese MiG ran out of fuel,[42] causing the pilots to eject, a North Vietnamese SAM shot down a NVAF MiG-17 while in "hot pursuit of a drone." While another NVAF MiG-17 shot down another MiG which got into his line of fire while chasing a drone.[43]

Between 1967 and until near the end of the U.S. involvement with the war in 1972, varied models of the 147SC Lightning Bug flew over half the missions over enemy territory. The average sortie per drone was three missions, before it was lost. The most famous *Lightning Bug* was a 147SC drone named "Tom Cat." *Tom Cat* flew sixty-eight missions before an enemy gunner finally brought him "down over Hanoi on September 25, 1974."[44] From August 1964, until their last combat flight on 30 April 1975 (the fall of Saigon), the USAF 100th Strategic Reconnaissance Wing would launch 3,435 Ryan reconnaissance drones over North Vietnam and its surrounding areas, at a cost of about 554 UAVs lost to all causes during the war.[45][46]

Iran–Iraq War

During the Iran–Iraq War, Iran sought the need for a new recon platform in addition to the RF-4. In the early 1980s, development of the Qods Mohajer-1 began, and production began in 1985. They were operated by the IRGC's Raad brigade in many key battles of the war, including Operation Karbala 5 and Operation Valfajr 8. They participated in 619 various missions, taking nearly 54,000 photographs.[47] Iran also armed them with RPGs, as some images show, however it is unknown if they were used in combat with that configuration.[48]

Post-war reflections

The usefulness of robot aircraft for reconnaissance had been demonstrated in Vietnam. At the same time, early steps were being taken to use them in active combat at sea and on land, but battlefield Unmanned aerial vehicles (UAV) would not come into their own until the 1980s.

During the early years, target drones were often launched from aircraft; or off a rail using solid-fuel rocket-assisted takeoff (RATO) boosters; or hydraulic, electromagnetic, or pneumatic catapult. Very small target drones can be launched by an elastic bungee catapult. Few target drones have landing gear, and so they are generally recovered by parachute or, in some cases, by

a skid landing. Beginning in April 1966, and lasting through the end of the war in 1975, the USAF successfully conducted approximately 2,655 Mid-Air Retrieval System (MARS) catches, out of 2,745 attempts, primarily using the Ryan 147J model drone.[49]

The most combat sorties flown during the war were made by the Ryan 147SC (military designation AQM-34L) with 1,651 missions. About 211 AQM-34Ls were lost during the war. The highest mission bird was a 147SC, named "Tom Cat", it accomplished 68 combat missions in Vietnam, before failing to return on 25 September 1974. *Tom Cat* was followed by *Budweiser* (with 63 missions), *Ryan's Daughter* (52 missions), and *Baby Duck* (46 missions).[50]

The largest UAVs in Vietnam were the 147T, TE, and TF (Military model AQM-34P, 34Q, and 34R). These machines were 30' long, and had 32' wing spans, with 2,800 lb thrust engines. These flew 28, 268, and 216 combat sorties respectively; of which 23 AQM-34Q drones were lost, AQM-34R machines were destroyed, and 6 AQM-34P models never made it home.[50]

War on Terror

The use of armed drones came into its own with the start of the War on Terror. The global audience was exposed to armed drones and their lethal uses when after the September 11, 2001 attacks an American UAV killed Qaed Salim Sinan al-Harethi (aka Abu Ali al-Harithi) in a November 2002 drone strike that killed six people, including Qaed, the alleged mastermind of the 2000 USS Cole bombing.

Battlefield UAVs

The attitude towards UAVs, which were often seen as unreliable and expensive toys, changed dramatically with the Israeli Air Force's victory over the Syrian Air Force in 1982. Israel's coordinated use of UAVs alongside manned aircraft allowed the state to quickly destroy dozens of Syrian aircraft with minimal losses. Israeli drones were used as electronic decoys, electronic jammers as well as for real time video reconnaissance.[51]

The US military is entering a new era in which UAVs will be critical to SIGINT payloads, or Electronic countermeasures systems should be in widespread use following 2010, with the UAVs controlled and relaying data back over high-bandwidth data links in real time, linked to ground, air, sea, and space platforms. The trend had been emerging before the American war in Afghanistan began in 2001, but was greatly accelerated by the use of UAVs in that conflict. The Predator RQ-1L UAV (General Atomics) was the first deployed UAV to the Balkans in 1995 Iraq in 1996 and was proved very effective in Operation Iraqi Freedom as well as Afghanistan.

Miniature and Micro UAVs

Another growth field in UAVs are miniature UAVs, ranging from "micro aerial vehicles (MAVs)" and miniature UAVs that can be carried by an infantryman to UAVs that can be carried and launched like an infantry man-portable air-defense system.

Endurance UAVs

The idea of designing a UAV that could remain in the air for a long time has been around for decades, but only became an operational reality in the 21st century. Endurance UAVs for low-altitude and high-altitude operation, the latter sometimes referred to as "high-altitude long-endurance (HALE)" UAVs, are now in full service.[52]

On August 21, 1998, an AAI Aerosonde named *Laima* becomes the first UAV to cross the Atlantic Ocean, completing the flight in 26 hours.

Beamed power UAV experiments

The idea of using UAVs as a cheaper alternative to satellites for atmospheric research, earth and weather observation, and particularly communications goes back at least to the late 1950s, with conceptual studies focused on UAVs with conventional propulsion, or new forms of propulsion using microwave beamed power or photovoltaic solar cells.

Raytheon suggested what would now be described as a UAV using beamed power, flying at an altitude of 15 kilometers (9.3 mi), as far back as 1959, and actually performed a proof-of-concept demonstration in 1964, with a transmitting antenna powering a helicopter on a 20-meter (65 foot) tether. The helicopter carried a rectifying antenna or "rectenna" array incorporating thousands of diodes to convert the microwave beam into useful electrical power.

The 1964 demonstration received a good deal of publicity, but nothing came of it, since enthusiasm for Earth satellites was very high and the rectenna system was heavy and inefficient. However, in the 1970s, NASA became interested in beamed power for space applications, and, in 1982, published a design for a much lighter and cheaper rectenna system.

The NASA rectenna was made of a thin plastic film, with dipole antennas and receiving circuits embedded in its surface. In 1987, the Canadian Communications Research Center used such an improved rectenna to power a UAV with a wingspan of 5 meters (16 feet 5 inches) and a weight of 4.5 kilograms (9.9 pounds), as part of the Stationary High Altitude Relay Platform (SHARP) project. The SHARP UAV flew in a circle at 150 meters (490 feet) above a transmitting antenna.

The UAV required 150 watts, and was able to obtain this level of power from the 6 to 12 kilowatt microwave beam.

Solar power

DARPA's *Vulture*, an ultra-long endurance aircraft

In the 1980s, new attention was focused on aircraft propelled by solar power. Solar photovoltaic (PV) cells, are not very efficient, and the amount of power provided by the Sun over a unit area is relatively modest. A solar-powered aircraft must be lightly built to allow low-powered electric motors to get it off the ground. Such aircraft had been developed in the competition for the Kremer prize for human-powered flight. In the early 1970s, Dr. Paul B. MacCready and his AeroVironment company took a fresh look at the challenge, and came up with an unorthodox aircraft, the "Gossamer Condor", to win the Kremer Prize on 23 August 1977.

In 1980, Dupont Corporation backed AeroVironment in an attempt to build a solar-powered piloted aircraft that could fly from Paris, France, to England. The first prototype, the "Gossamer Penguin", was fragile and not very airworthy, but led to a better aircraft, the "Solar Challenger". This success led in turn to AeroVironment concepts for a solar-powered UAV. A solar-powered UAV could in principle stay aloft indefinitely, as long as it had a power-storage system to keep it flying at night. The aerodynamics of such an aircraft were challenging, since to reach high altitudes it had to be much lighter per unit area of wing surface than the Solar Challenger, and finding an energy storage system with the necessary high capacity and light weight was troublesome as well.

In 1983, AeroVironment investigated the concept, which was designated "High Altitude Solar (HALSOL)". The HALSOL prototype first flew in June 1983. HALSOL was a simple flying wing, with a span of 30 meters (98 feet 5 inches) and a width of 2.44 meters (8 feet). The main wing spar was made of carbon fiber composite tubing, with ribs made of styrofoam and braced with spruce and Kevlar, and covered with thin Mylar plastic film. The wing was light but remarkably strong.

The wing was built in five segments of equal span. Two gondolas hung from the center segment, which carried payload, radio control and telemetry electronics, and other gear. The gondolas also provided the landing gear. Each gondola had dual baby-buggy wheels in front and a bicycle wheel in back for landing gear. HALSOL was propelled by eight small electric motors driving variable-pitch propellers. There were two motors on the center wing segment, two motors on each inner wing segment, and one motor on each outer wing segment. The aircraft's total weight was about 185 kilograms (410 pounds), with about a tenth of that being payload.

Nine HALSOL flights took place in the summer of 1983 at the isolated and secret Groom Lake base in Nevada. The flights were conducted using radio control and battery power, as the aircraft had not been fitted with solar cells. HALSOL's aerodynamics were validated, but the investigation led to the conclusion that neither PV cell nor energy storage technology were mature enough to make the idea practical for the time being. HALSOL was put into storage, and as it turned out, would be resurrected for greater glories later, as discussed later. For the moment, though, it remained a complete secret.

In the mid-1980s, not long after HALSOL went into mothballs, NASA awarded a contract to Lockheed to study a solar-powered HALE UAV named the "Solar High Altitude Powered Platform (Solar HAPP)" for missions such as crop monitoring, military reconnaissance, and communications relay. The Solar HAPP effort did not result in a prototype. Solar-powered HALE UAVs were a concept a bit ahead of their time, and early practical work on endurance UAVs focused on more conventional concepts.

Amber

In 1984, under a joint program (Teal Rain) with the U.S. Navy, DARPA issued a contract to Leading Systems Incorporated (LSI), based in Irvine, California, and led by Abraham Karem, to build an endurance UAV named "Amber"[53][54]. Amber was to be used for photographic reconnaissance, ELINT missions, or as a cruise missile.

Amber was approximately 4.6 meters (15 feet) long, had a wingspan of 8.54 meters (28 feet), weighed 335 kilograms (740 pounds), and was powered by a four-cylinder liquid-cooled piston engine providing 49 kW (65 hp), driving a pusher propeller in the tail. The wing was mounted on a short pylon above the fuselage. The cruise missile version of Amber would discard the wing when it made its final dive on a target.[54]

Amber had an inverted v-tail, which would prove a popular configuration for a pusher UAV, since it protected the propeller during takeoff and landing. The airframe was made of plastic and composite materials, mostly Kevlar, and the UAV had retractable stiltlike tricycle landing gear to ensure propeller clearance. Amber had a flight endurance of 38 hours or more.

The initial contract specified three "Basic Amber" A-45 cruise missile prototypes and three B-45 reconnaissance prototypes. Initial flights were in November 1986, with long-endurance flights the next year. Up to this time, Amber was a deep secret, but in 1987 details of the program were released.

Amber was only one of a number of different US UAV programs in planning at the time, and the US Congress became impatient with what was perceived as confusion and duplication of effort. Congress ordered a consolidation of UAV programs in 1987, freezing funding until June 1988, when the centralized Joint Program Office for UAV development, mentioned earlier, was established. Amber survived the consolidation of UAV efforts into JPO, resulting in the first "Amber I" reconnaissance UAV, which first flew in October 1989. Seven Amber Is were built, and were used in evaluations along with Basic Ambers through 1990. However, funding for reconnaissance assets was being cut, and in 1990 the Amber program was killed. LSI was faced with bankruptcy, and was bought out by General Atomics in 1991, who would later develop the Amber into an operational platform, the MQ-1 Predator.[55]

U.S. domestic use

The U.S. Customs and Border Protection agency has experimented with several models of UAVs, and has begun purchasing a fleet of unarmed MQ-9 Reapers to survey the U.S. border with Mexico. "In more than six months of service, the Predator's surveillance aided in nearly 3900 arrests and the seizure of four tons of marijuana", border officials say.[56]

On May 18, 2006, the Federal Aviation Administration (FAA) issued a certificate of authorization which will allow the M/RQ-1 and M/RQ-9 aircraft to be used within U.S. civilian airspace to search for survivors of disasters. Requests had been made in 2005 for the aircraft to be used in search and rescue operations following Hurricane Katrina, but because there was no FAA authorization in place at the time, the assets were not used. The Predator's infrared camera with digitally enhanced zoom has the capability of identifying the heat signature of a human body from an altitude of 10,000 feet, making the aircraft an ideal search and rescue tool.[57]

According to a 2006 *Wall Street Journal* report, "After distinguished service in war zones in recent years, unmanned planes are hitting turbulence as they battle to join airliners and weekend pilots in America's civilian skies. Drones face regulatory, safety and technological hurdles – even though demand for them is burgeoning. Government agencies want them for disaster relief, border surveillance and wildfire fighting, while private companies hope to one day use drones for a wide variety of tasks, such as inspecting pipelines and spraying pesticides on farms."[56]

Recreational drones became popular in the United States in 2015, with approximately one million expected to be sold by the end of the year.[58]

Drones Over Canada

The Government of Canada is considering the purchase of UAV's for arctic surveillance. The Canadian government wants to buy at least three high-altitude, unmanned aerial vehicles for potential Arctic use. The Canadian government wants to modify the existing Global Hawk drone, which can operate at 20,000 metres, to meet the rigours of flying in Canada's Far North.[59]

Small-player use

At one time the cost of miniature technology limited the usage of UAVs to larger and better funded groups such as the US military, but due to falling costs of UAV technology, including vehicles and monitoring equipment in their simpler forms, it has become available to groups that before would not have had the funding to use it. Beginning in 2004, it was reported that the Lebanese Shi'ite militia organization Hezbollah began operating the Mirsad-1 UAV, with the stated goal of arming the aircraft for cross-border attacks into Israel.[60] According to one blogger, however, the drone was an actually an Iranian Ababil-2 loitering munition.[61] Iranian-backed militias across the Middle East now operate advanced UAVs, including the Houthis in Yemen who used Samad drones in an effective attack on Aramco facilities in Saudi Arabia in 2019.

See also

- Battlefield UAVs in the United States
- History of unmanned combat aerial vehicles
- British unmanned aerial vehicles of World War I
- List of military aircraft of the United States
- List of unmanned aerial vehicles
- Miniature UAVs
- Modern US endurance UAVs
- Unmanned combat aerial vehicle

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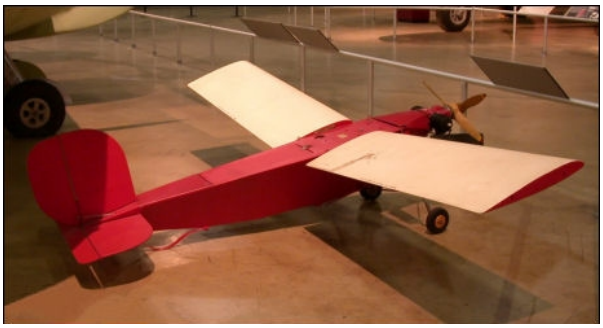
Radioplane OQ-2

The **Radioplane OQ-2** was the first mass-produced unmanned aerial vehicle or drone in the United States, manufactured by the Radioplane Company. A follow-on version, the OQ-3, became the most widely used target drone in US service, with over 9,400 being built during World War II.

History

Marilyn Monroe with an RP-5's propeller

RQ-4, OQ-2, OQ-3, OQ-7, OQ-13, OQ-14, and TDD	
	
General information	
Type	Target drone
National origin	United States
Manufacturer	Radioplane
Primary user	USAAF
Number built	ca. 15,000
History	
First flight	1939

The OQ-2 was originally a radio-controlled aircraft model designed by Walter Righter. The design, along with its engine design, was purchased by actor Reginald Denny, who had demonstrated another model to the US Army in 1940. Calling the new design the RP-2, he demonstrated several updated versions to the Army as the RP-2, RP-3 and RP-4 in 1939.[1]

In 1940, the Army placed an order for 53 RP-4s (some sources refer to the RP-4 as **OQ-1**. but that designation was never assigned). This small order led to a much bigger 1941 order for the similar RP-5, which became the US Army **OQ-2**, the *OQ* meaning a "subscale target". The US Navy also bought the drone, designating it **TDD-1**, for *Target Drone, Denny, 1*. Thousands were built, manufactured at the Radioplane plant at the Van Nuys Airport in the Los Angeles metropolitan area.

It was at this factory on June 26, 1945, that David Conover, an Army photographer, shot pictures of a young woman assembler named Norma Jeane Dougherty. Thinking she had potential as a model, he invited her to pose, and his encouragment led her to pursue work at a modeling

agency, where her success prompted her to take a screen test and begin an acting career as Marilyn Monroe.[2]

Description and variants

The OQ-2 is a simple aircraft, powered by a two-cylinder two-cycle piston engine, providing 6 horsepower (4.5 kW) and driving two contra-rotating propellers. The RC control system was built by Bendix. Launching was by catapult only and recovery by parachute, should it survive the target practice. The landing gear was used only on the OQ-2 versions as sold to the Army to cushion the landing by parachute. None of the drones including the improved variants shipped to the Navy had landing gear. The subsequent variants delivered to the Army did not have landing gear.

The OQ-2 led to a series of similar but improved variants, with the **OQ-3** / **TDD-2** and **OQ-14** / **TDD-3** produced in quantity. A number of other target drones were built by Radioplane (including licensed contractors) and competing companies during the war, most of which never got beyond prototype stage, which accounts for the gaps in the designation sequence between "OQ-3" and "OQ-14".

After World War II ended, various experiment were made with Radioplane target drones. In one experiment in 1950, a derivative of the QQ-3 Radioplane drone was used to lay military communication wire.[3]

During the war Radioplane manufactured nearly fifteen thousand drones. The company was bought by Northrop in 1952.

Surviving aircraft

OQ-2 on display at the Aviation Unmanned Vehicle Museum

- OQ-2 on display at the National Museum of the United States Air Force in Dayton, Ohio.[4]
- OQ-2 on display at the March Field Air Museum in Riverside, California.[5]
- OQ-2 on display at the Aviation Unmanned Vehicle Museum in Caddo Mills, Texas.[6]
- OQ-2 or OQ-3 on display at the National Warplane Museum in Geneseo, New York.[7]

- RP-5A on display at the Western Museum of Flight in Torrance, California.[8]
- OQ-2A on display at the National Model Aviation Museum in Muncie, Indiana.[9][10][11]
- OQ-2A on display at the Museum of the American G.I. in College Station, Texas.[12]
- OQ-2A on display at the Air and Military Museum of the Ozarks in Springfield, Missouri.[13]
- OQ-3 on display at the Pima Air & Space Museum in Tucson, Arizona.[14]
- OQ-3 on display at the United States Army Aviation Museum at Fort Novosel near Daleville, Alabama.[15]
- OQ-14 in storage at the National Air and Space Museum in Washington, D.C.[16][17][18]

Specifications (OQ-2)

General characteristics

- **Length:** 8 ft 8 in (2.65 m)
- **Wingspan:** 12 ft 3 in (3.73 m)
- **Gross weight:** 104 lb (47 kg)
- **Powerplant:** 1 × Righter O-15-1 , 7 hp (5 kW)

Performance

- **Maximum speed:** 85 mph (137 km/h, 74 kn)
- **Endurance:** 1 hour

See also

- History of unmanned aerial vehicles § Reginald Denny and the Radioplane

Related lists

- List of military aircraft of the United States

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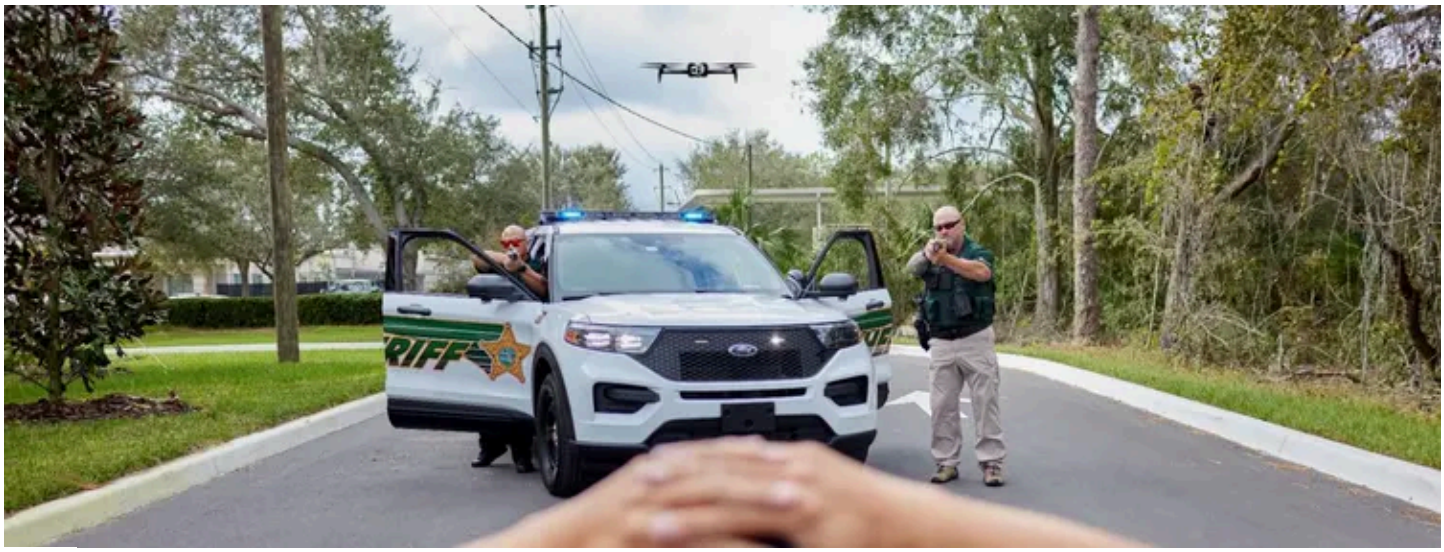
External links

- "The Radioplane Target Drone" (http://www.ctie.monash.edu/hargrave/rpav_radioplane4.html) Archived (https://web.archive.org/web/20220521223518/https://www.ctie.monash.edu/hargrave/rpav_radioplane4.html) 2022-05-21 at the Wayback Machine a complete history of Radioplane in the World War II era.

ARTICLE

The complete history of drones for police and law enforcement

Resource Center



How drones have evolved to become essential tools for law enforcement and first responders

Although today they are a relatively common sight, drones were once rare and fantastical. Remote piloting an aircraft seemed like something out of science fiction. However, the history of drones might surprise you, beginning some 200 years ago with unmanned balloons.

Today, drones are both more common and more complex, playing host to cameras, GPS devices, infrared sensors, and more. A modern, human-operated drone can take pictures, perform search-and-rescue operations, and even serve as a first responder in areas too remote for land vehicles, and new applications are being developed every day.

From their beginnings as a search and rescue tool to the drones of today that can be deployed from almost anywhere, the history of drones in law

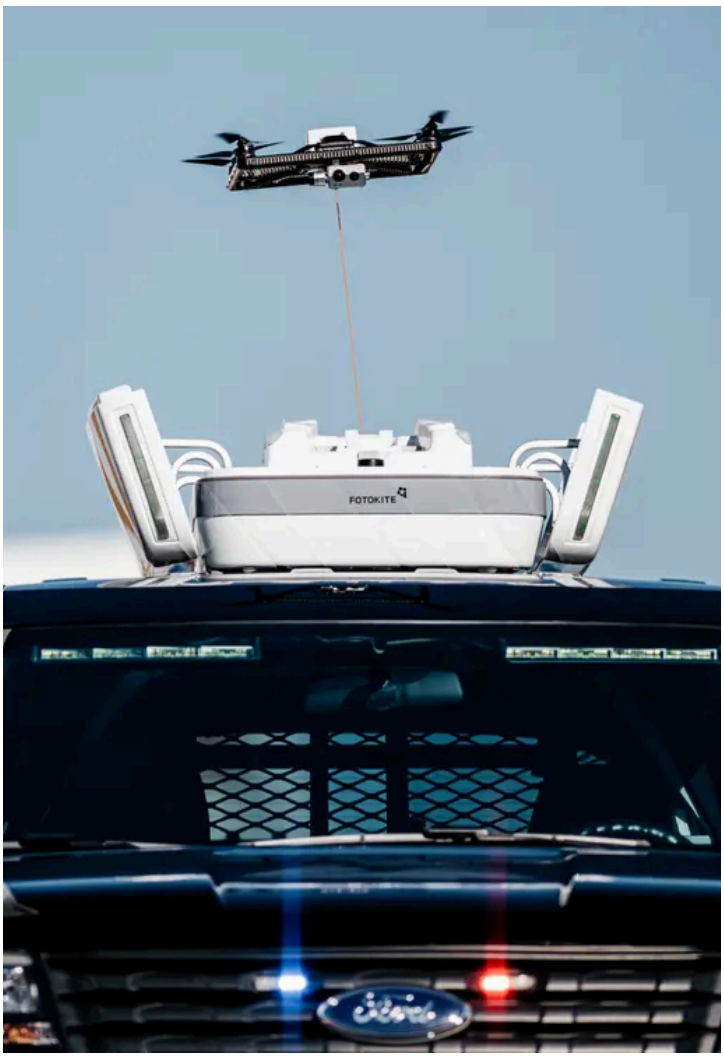
enforcement is a journey through the evolution of both aeronautics and technology, and it begins in France over 200 years ago.

For more information, read Police drones: the complete guide.

How to develop a public safety drone program from the ground up

Learn the strategies experts use to build drone programs.

Download the guide



The first drones

The history of drone technology is both older than you would expect and more bizarre. Unmanned Aerial Vehicles, or UAVs, have been around since the late 18th Century, when the Montgolfier Brothers hoisted a variety of livestock aloft in unmanned balloons. UAVs were first used as a weapon of war in 1849 when the Austrian army lofted a fleet of unmanned balloons loaded with explosives over the city of Venice to punish its citizens for staging a revolt. Although neither of these events utilized what we would consider “drone” technology today, they presaged the coming of a

modern trend: deploying unmanned aerial vehicles to do work humans couldn't – or didn't want to – do.

The history of what we might recognize as drones today began during World War I when airplanes guided by radio were used to attack zeppelins. Development of radio-controlled airplanes continued after the war, with better, faster, and, more importantly, smaller drones taking flight. Various experiments with drone technology were conducted throughout the intervening years, culminating in the development of small, fast, and easily controlled drones in the 1970s. Used mainly by the military throughout the end of the 20th Century, the first modern drones were the size of small aircraft and were deployed for reconnaissance missions, jamming enemy radar, as well as serving as decoys.

Advances in computerization, miniaturization, and the invention of GPS combined to make the modern drone – a small, lightweight, accurate, human-controlled aircraft – a reality in the 1990s. This wave of innovations culminated in the creation of drones like the Predator (which saw extensive use during the 1991 Gulf War) and would eventually lead to the creation of commercial drones used by police.

The history of drones in law enforcement

The first drone used by civilian law enforcement agencies was a custom-designed reconnaissance drone called the Spectra, designed by retired US Air Force medic Gene Robinson. Robinson's drone was used unsuccessfully to locate a missing retired special education teacher named Margaret White, who disappeared along a stretch of highway in Hays County, Texas in 2005. White was eventually located by cadaver dogs, the victim of a fatal snakebite.

Although the initial drone search failed to locate White, further review of the drone photographs clearly revealed her body right where she was eventually found. The technology hadn't failed; rather, it was the first time searchers had utilized aerial drone photography in a search and quite literally didn't realize what they were seeing. The Spectra drone was used again that same year in the search for former beauty queen Tara Grinstead in Irwin County, Georgia, and has been used hundreds of times since.

The first law enforcement drones were either custom-made, like the Spectra, or repurposed military drones, like the Predator, which was used to apprehend an actual cattle rustler in North Dakota in 2011. Six of his neighbor's cows wandered onto Rodney Brossart's property, and after

Brossart refused to return them, a SWAT team was called to apprehend him. Local law enforcement utilized a Predator drone on loan from the Department of Homeland Security's Customs and Border Patrol to ascertain the location of Brossart and his three sons, all of whom were armed. Brossart was then safely apprehended with the use of a TASER energy weapon.

Commercial production of drones began in the mid-2000s and reached a fever pitch in the mid-2010s with the release of the successful DJI Phantom, which utilized GPS and a GoPro brand action camera. Since then, law enforcement agencies have adopted drones of all kinds, from consumer-grade drones to enterprise-level drones created specifically for police agencies and first responders.

Vern Sallee, lead strategist for Axon's end-to-end drone solution (Axon Air), helped create the first DFR program in the country at the Chula Vista Police Department, where he served as captain. Over two years, the agency ran over 6,000 DFR missions and dropped the average call response time to under 2.5 minutes. Chula Vista's DFR program has continued to perform since Sallee left the department to join Axon. The DFR mission count now exceeds 12,000 — around 25% of which were resolved without the need to deploy ground units.

Drones used by police are currently deployed for a variety of law enforcement purposes. As modern drones have become smaller, better equipped, and able to stay aloft for longer periods, they have been adopted for use by more and more agencies. As of January 2023, it was estimated that over 5,000 public safety agencies across the country were employing drones.

Although still controversial due to ethical and privacy concerns, drones have positively influenced law enforcement by introducing new methods and enhancing the safety of officers on the ground. Through a variety of use cases, law enforcement officers are now able to acquire live video and other critical data quickly and remotely. Drones and their advanced capabilities have also enhanced multiple areas of policing through the use of high-resolution cameras and 3D imaging.

Search and rescue

As with the first law enforcement uses of drones, search and rescue (SAR) remains a mission focus for law enforcement drones. Able to reach remote areas quickly, drones are invaluable tools for missing person searches. Searchers are able to use drones to map remote areas with onboard cameras, pinpoint precise locations using GPS, and can even detect trapped or hidden persons using infrared cameras.

A prime example of the successful deployment of drones for SAR was in 2017 after Hurricane Harvey hit Houston, Texas. Law enforcement in Texas used drones equipped with high-resolution cameras to locate people stranded by floodwaters and transmit their locations to rescuers.

Another famous use of drones for SAR came in 2018 when they were used in Thailand to assist in the rescue of a youth soccer team and their coach who had become trapped in a cave during heavy flooding. The drones were used to locate possible cave entrances.

Incident investigations

The ability of drones to arrive onsite quickly makes them ideal for responding to traffic accidents. Law enforcement agencies across the country are employing drones to supply first responders with real-time visibility of the scene before their arrival. Once on the scene, they create 3D imagery of the accident scenes to determine the sequence of events leading to the accident. High-resolution images and 3D renderings provide investigators with an unmatched level of detail about a crime scene that they can revisit again and again using evidence management software like Axon Evidence.

Incident overwatch

A police helicopter hovering over a crime scene or a police chase is a common sight, but more and more departments are turning to drones to serve the same functions as police helicopters. Drones are both quieter than helicopters and less expensive, making them a go-to choice for operations from suspect chases to remote reconnaissance.

Situational awareness of large gatherings

Large events, public gatherings, and incidents of civil disobedience are other areas where drones can be invaluable. Able to hover quietly high above the ground, drones can safely monitor groups of people and traffic patterns to help law enforcement assess problem areas and direct officers to where they are most needed. Drones equipped with infrared can also be utilized to detect body heat in hard-to-reach locations, enhancing officers' ability to monitor perimeters.

FAA drone regulations

Since 2016, the Federal Aviation Administration (FAA) has regulated drone use in the United States, requiring drone pilots to follow FAA regulations. The FAA's regulations mainly dictate where drones cannot be

flown, such as around airports. As of early 2023, the FAA reported it had registered over 871,000 drones and 307,000 certified Remote Pilots.

As the sheer volume of drones in the sky continues to increase, police drone operators will have to contend with civilian drones invading crime scenes and potentially hindering police drone use. While there have been no reports yet of drones substantially hindering police work, firefighters have been repeatedly in the crosshairs of the drone invasion.

In 2015, firefighters in New York State used their hoses to ground a drone that had invaded the scene of an active fire. Again, in 2017, firefighters in California's wine country reported drone interference at the scene of an active wildfire, and at least one drone pilot was arrested.

The California Senate introduced a bill in 2015 that would allow law enforcement officers to shoot down drones interfering with their work, but that bill was vetoed by then-Governor Jerry Brown. Meanwhile, in Utah, lawmakers successfully passed a similar measure. It remains to be seen if more jurisdictions will follow suit.

The future of drones in law enforcement

As drones become more technologically advanced and police departments become more adept at using them, it can be expected that the use cases for deploying drones will multiply. As with any new technology, having it in hand will encourage more active use, and it is expected that police departments will discover or invent new uses for drones.

Battery capacity is one major area where we can expect to see a dramatic improvement in the future. Drone use is currently limited by the amount of power a drone's battery can hold. Once the battery drains, the drone must leave the field. Advanced batteries will hold a longer charge, allowing them to remain on-scene for longer and extending their usability.

Greater battery life will only compound the ability of ground-based airspace systems operating beyond visual line of sight (BVLOS) to provide support and intelligence to personnel on the ground. Drones can go further and see more, making them a force multiplier for any team, but particularly those charged with protecting larger areas.

In addition, advances in artificial intelligence could lead to fully autonomous drones, removing the human pilot from the equation altogether. Autonomous drones could fly unattended over cities or crime

scenes, even following suspects or officers through complex structures that might hinder a human pilot.

For information on how Axon Air can help you manage your drone fleet from anywhere, visit the Axon Air product page or reach out to one of our experts.

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History of unmanned combat aerial vehicles

The **history of unmanned combat aerial vehicles** (UCAVs) is closely tied to the general history of unmanned aerial vehicles (UAVs). While the technology dates back at least as far as the 1940s, common usage in live operations came in the 2000s. UCAVs have now become an important part of modern warfare, including in the Syrian civil war, the 2020 Nagorno-Karabakh war and during the 2022 Russian invasion of Ukraine.

Turkish Bayraktar Akıncı UCAV with its weaponry including SOM air-launched cruise missiles

Early years

In July 1849, during the siege of Venice, the Austrian forces used unmanned balloons to drop bombs on the city.[1][2]

The Hewitt-Sperry Automatic Airplane, which first flew in 1917, was a US-developed flying bomb. The project continued through to 1925.[3] The RAE Larynx was a similar project in the UK that ran from 1925 to 1929.[4]

One of the earliest explorations of the concept of the combat drone was by Lee de Forest, an early inventor of radio devices, and U. A. Sanabria, a TV engineer. They presented their idea in an article in a 1940 publication of *Popular Mechanics*.[5]

Operation Aphrodite in 1944 saw the USAAF and US Navy using radio-controlled, unmanned bombers as precision-guided munitions.[6]

The Interstate TDR was a purpose-built unmanned aerial combat vehicle that saw some use in WWII.

The V-1 flying bomb was an early cruise missile used extensively by Nazi Germany 1944-5.

Cold War era 1945–1992

During the 1960s the US Navy installed thousands of QH-50 DASH torpedo-launching helicopter drones on many of their destroyers. They were meant as a stopgap measure to counter the threat of an ever-growing fleet of Soviet attack submarines. The entire fleet was retired when larger destroyers were introduced, permitting the use of manned helicopters to launch the same kind of torpedo, and the use of more powerful rocket-assisted torpedo systems.

In 1971, John Stuart Foster Jr., a nuclear physicist and former head of the Lawrence Livermore National Laboratory (then called the Lawrence Radiation Laboratory),[7] was a model aeroplane hobbyist and had the idea this hobby could be applied to building weapons.[7] He drew up plans and by 1973 DARPA (Defense Advanced Research Projects Agency) built two prototypes called "Prairie" and "Calera". They were powered by a modified lawn-mower engine and could stay aloft for two hours while carrying a 28-pound (13 kg) load.[7]

If UAVs could be used for reconnaissance by the army and the air force, it was obvious that they could also be used for active combat missions, at least in principle. In practice, shooting at a specific ground target is much trickier than flying over an area and taking pictures, and it wasn't until the 1970s that the US Air Force seriously experimented with the concept. The objective was to study an attack system to perform the dangerous "suppression of enemy air defenses (SEAD)" mission, or in other words to destroy enemy anti-aircraft gun and SAM sites. The project was known as **HAVE LEMON**. HAVE LEMON involved a number of Ryan Firebees equipped with a weapons pylon under each wing, a forward-looking TV camera, and a datalink mounted in a pod on top of the vertical tailplane. These UAVs were given the designation "BGM-34A" and used beginning in late 1971 to perform remote-control strikes on simulated air-defense sites with Maverick missiles and HOBOS TV-guided glide bombs.

Ryan Firebee

The results were good enough to permit follow-on development, resulting in the BGM-34B, which featured an extended nose to accommodate an infrared imaging system (some sources say low-light-level TV) and laser designator for targeting and control of laser-guided bombs. Tests performed in 1973 and 1974 with the BGM-34B were also successful, and led Teledyne Ryan to

develop a BGM-34C as a conversion of existing Lightning Bug airframes. The BGM-34C could be used for reconnaissance or strike missions by swapping out nose modules and other elements.

The concept proved to be a little too far ahead of its time. Nobody in the Air Force hierarchy stepped forward to take ownership of the issue, and the HAVE LEMON exercise faded away. The test squadron was disbanded in 1979 and its roughly 60 UAVs were put into storage. However, in the summer of 2003 a UAV "airshow" of sorts was conducted, in which a Firebee was displayed carrying two Hellfire anti-armor missiles, as well as a pod for dispensing remote battlefield sensors.

As attention focused on the combat capabilities of attack drones, the USN and USAF were looking for drones that could turn 6Gs and quickly roll into tight turns. While at the same time, US designers were wondering if dog-fights between robot planes were just around the corner.[8] From 25 January-28 April 1971, a batch of Maneuverability Augmentation System for Tactical Air Combat Simulation (MASTACS) systems were modified onto existing US Navy BQM-34A drones. These UAVs were test flown to evaluate their maneuvering characteristics, which were deemed good.[8] On 10 May 1971, the MASTACS exercise was ready to commence off the coast of California, against two USN F-4 Phantom IIs flown by Vietnam combat experienced pilots. The F-4s were equipped with both the infrared homing Sidewinder and radar-guided Sparrow air-to-air missiles.[9] As the two F-4s approached Santa Catalina Island, a MASTAC-equipped Firebee was ground-launched. The F-4s were vectored towards the interception and the air-to-air battle was on. No restrictions were placed on the F-4 pilots, the air battle was to be a "no holds barred contest",[9] with the very real possibility of a Phantom being rammed by a UAV as it maneuvered during the dogfight. The first action was a head-on maneuver, as the Phantom lined up for the kill, the UAV (drone) pulled a high-G turn and flew over the F-4's canopy. The Firebee was banking into 100-degree maneuvers, and making 180-degree reversal turns within 12 seconds.[9] The Phantoms were no longer attacking the UAV, they were now the targets.[9] The UAVs had been able to pull and hold 6 Gs within three seconds of receiving the command, and still maintain altitude. The Phantoms were unable to maintain track on the UAV, but fired their air-to-air missiles anyway, receiving no hits.[10]

In the 1973 Yom Kippur War, Israel used unarmed U.S. Ryan Firebee target drones to spur Egypt into firing its entire arsenal of anti-aircraft missiles. This mission was accomplished with no injuries to Israeli pilots, who soon exploited the depleted Egyptian defences. In the late 1970s and 80s, Israel developed the Scout and the Pioneer, which represented a shift toward the lighter, glider-type model of UAV in use today. Israel pioneered the use of unmanned aerial vehicles (UAVs) for real-time surveillance, electronic warfare, and decoys.[11][12][13] The images and radar decoying provided by these UAVs helped Israel to completely neutralize the Syrian air defences in Operation Mole Cricket 19 at the start of the 1982 Lebanon War, resulting in no pilots downed.[14]

In the late 1980s, Iran deployed a drone armed with six RPG-7 rounds in the Iran–Iraq War.[15]

1990s

Over the next two decades, more reliable communications links were developed, automated systems came into much wider use, and the military learned to be much more comfortable with such new technologies. In the late 1990s, the concept of using UAVs for performing actual combat, was revived in the form of various designs generally designated as "uninhabited combat air vehicles".

One of the initial concepts was to develop a UCAV on a fast track for "air occupation". The idea was to use unpiloted aircraft to fly continuous patrols over hostile territory, with some of the aircraft fitted with sophisticated sensors to identify enemy activities and target them, and other aircraft following up with attacks. The idea was obviously inspired by USAF air patrols over Iraq and the Balkans.

The United States Navy also began studies for UCAVs at about the same time. The Navy saw that UCAVs had a number of potential benefits. They promised to be cheaper than manned aircraft, with a lower purchase cost and much lower operating costs, since operators could be given much of their training through simulations. UCAVs would also be smaller and stealthier than manned aircraft, and could perform high-G maneuvers impossible with piloted aircraft, allowing them to dodge missiles and enemy fighters. Indeed, since the Navy found themselves increasingly committed to the use of expensive cruise missiles to perform punitive strikes and other limited military operations, UCAVs offered a potentially cheaper alternative, a "reusable cruise missile". One UCAV could carry a number of smart GPS-guided munitions and hit multiple targets on a single sortie, and then return home to be used again. Even with a high combat attrition rate, the cost would be less than that of a barrage of cruise missiles.

UCAVs missions would be conducted by an operator in a ground vehicle, warship, or control aircraft over a high speed digital data link. The operator would not really be flying the UCAV directly, however, since the robot would be able to handle the details of flight operations by itself, leaving the operator in a supervisory role. The UCAV would be able to complete its mission autonomously if communications were cut.

Impressed by Israel's success, the US quickly acquired a number of UAVs, and its Hunter and Pioneer systems are direct derivatives of Israeli models. The first 'UAV war' was the first Gulf War: according to a May 1991 Department of the Navy report: "At least one UAV was airborne at all times during Desert Storm." After the Gulf War successfully demonstrated its utility, global militaries invested widely in the domestic development of combat UAVs.[16]

2000s

The US increasingly used Predator drones following the invasion of Afghanistan, but the technology also became more widely available.[17] The US increased its use of drone strikes against targets in foreign countries and elsewhere as part of the War on Terror. In January 2014, it was estimated that 2,400 people had died from U.S. drone strikes in five years.[18] In June 2015, the total death toll of U.S. drone strikes was estimated to exceed 6,000.[19] The first "kill" by an American UAV was on October 7, 2001, in Kandahar.[20]

Both the US Air Force and Navy had been developing plans for operational follow-ons to their respective demonstrator programs, but pressures rose for the two services to merge their efforts, resulting in the formation of the Joint Unmanned Combat Air Systems (J-UCAS) program in October 2003 under DARPA direction. The goal of the J-UCAS effort was to select a single contractor to provide from 10 to 12 machines for operational evaluation in the 2007-8 time frame. In the 2006 Quadrennial Defense Review, it was stated that the J-UCAS program would be terminated and instead a new long-range strategic bomber program was launched.[21]

2010s

Turkey used drones against the Kurdistan Workers' Party in Turkey and in Syria during the Syrian civil war. Turkish drones were also used in the Libyan civil war in 2019.[22][23]

2020s

A Ukrainian Navy Bayraktar TB2 UCAV in July 2021

A Russian Orion in use during the invasion of Ukraine

In 2020, Turkey became the first country to use UCAVs in a large, coordinated attack on a conventional battlefield when they attacked forces in Syria. They were used to attack enemy positions, to provide cover for ground forces and to scout for artillery.[23]

Drones were used extensively in the 2020 Nagorno-Karabakh war between Azerbaijan and Armenia.[24] Azerbaijan's use of Turkish TB2 drones was seen as crucial in their defeat of the Armenian forces. They were used both to carry missiles and for reconnaissance, with their successful use linked to heavy losses among Armenian tanks and other armoured vehicles.[22] Armenian ground air defences were largely ineffective against UCAVs.[23] This success was seen as offering countries air power without the expense of a traditional air force.[17]

Drones were also used extensively during the 2022 Russian invasion of Ukraine.[25] Ukraine made extensive use of TB2s and other designs against Russia in 2022.[25] They also used octocopters to drop anti-tank grenades at night.[26] one example of a large-scale attack with drones was in October 2022, when Russia described a "massive" attack by UAVs and sea drones on their Black Sea Fleet at Sevastopol,[27] during which the flagship *Admiral Makarov* was damaged.[28]

Russia has also used drones against Ukrainian forces, including the Iranian-made Shahed-136 since September 2022.[29] Belarusian partisans in BYPOL also claimed to have used drones in a successful attack on a Russian military aircraft at the Machulishchy airfield in February 2023.[30]

The large number of drones deployed has also seen high rates of losses, with Ukraine estimated in 2023 to be losing 10,000 drones per month in active service.[31] Some commercial drones such as DJI Mavic and Phantom have been modified to carry light explosives for combat missions in recent wars.

Some reconnaissance drones that have armed capability include the CASC CH-92, IAI Eitan and the Ababil-3, Ababil-5, Hamaseh. Some commercial drones such as DJI Mavic and Phantom have been modified to carry light explosives for combat missions in recent wars. Ukraine has used converted light sports planes.[32]

Fighting between India and Pakistan in May 2025 also saw the extensive use of drones.[33]

External links

- Israel sets combat drones against missile launchers in Gaza (https://web.archive.org/web/20070513201916/http://www.worldtribune.com/worldtribune/07/front2454229.238888889.html) , World Tribune, May 8, 2007
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SPIES THAT FLY

Time Line of UAVs

Spies That Fly homepage

With their strange silhouettes and awe-inspiring capabilities, today's UAVs, like this Predator, seem to have flown in from the future. But the Predator and the dozen other operational UAVs in the U.S. military arsenal owe their existence to the past. They are only the most recent and advanced installments in a century-old history of unmanned warfare and surveillance from the skies. **Click on the UAV icons below to learn more about the Predator and some of its UAV ancestors.** — *Lexi Krock*

Pre-aviation UAVs

Years before the first manned airplane flight on December 17, 1903, primitive UAV technology was used for combat and surveillance in at least two wars.

PERLEY'S AERIAL BOMBER (USA) →

EDDY'S SURVEILLANCE KITE (USA) →

1910s

During World War I, the first UAVs took flight in the U.S. Though the success of UAVs in test flights was erratic, the military recognized their potential in combat. Armistice arrived before the prototype UAVs could be deployed in earnest.

SPERRY AERIAL TORPEDO (USA) →

KETTERING AERIAL TORPEDO (USA) →

1930s

For more than a decade after the end of World War I, development of pilotless aircraft in the U.S. and abroad declined sharply. By the mid-to-late 1930s, new UAVs emerged as an important combat training tool.

DH.82B QUEEN BEE (UK) →

RADIOPLANES (USA) →

1940s

During World War II, Nazi Germany's innovative V-1 demonstrated the formidable threat a UAV could pose in combat. America's attempts to eliminate the V-1 laid the groundwork for post-war UAV programs in the U.S.

V-1 (GERMANY) →

PB4Y-1 AND BQ-7 (USA) →

SUPERLATIVE UAVs THROUGH HISTORY

Fastest: D-21 (Mach 4)—USA

Highest: Helios (96,500 ft)—USA

Biggest (size): Helios (246-ft wingspan)—USA

Biggest (weight): RQ-4 Global Hawk (25,600 lbs)—USA

Smallest (size/weight): Black Widow (6-inch diameter/2.0 oz)—USA

Longest flight (duration): Heron UAV (52 hours)—Israel

Longest flight (distance): RQ-4 Global Hawk (8,580 miles) - USA

Most expensive: RQ-4 Global Hawk ($40 million)—USA

First Trans-Atlantic flight: Aerosonde (Aug. 20-21, 1998)—USA

First Trans-Pacific flight: RQ-4 Global Hawk (Apr. 22-23, 2001)—USA

1960s

From their early use as target drones and remotely piloted combat vehicles, UAVs took on a new role during the Vietnam War: stealth surveillance.

AQM-34 RYAN FIREBEE (USA) →

D-21 (USA) →

1970s

The success of the Firebee continued through the end of the Vietnam War. In the 1970s, while other countries began to develop their own advanced UAV systems, the U.S. set its sights on other kinds of UAVs.

FIREBEE 1241 (ISRAEL) →

RYAN SPA 147 (USA) →

1980s

During the late 1970s and throughout the 1980s, the Israeli Air Force, an aggressive UAV developer, pioneered several important new UAVs, versions of which were integrated into the UAV fleets of many other countries, including the U.S.

SCOUT (ISRAEL) →

PIONEER (ISRAEL) →

1990s to today

UAVs command a permanent and critical position in high-tech military arsenals today, from the U.S. and Europe to Asia and the Middle East. They also play peaceful roles as monitors of our Earth's environment.

FIREBIRD 2001 (ISRAEL) →

PATHFINDER (USA) →

DARKSTAR (USA) →

RQ-1 PREDATOR (USA) →

RQ-4 GLOBAL HAWK (USA) →

HELIOS (USA) →

The Future

The surveillance UAVs of tomorrow may evolve into MAVs, or micro aerial vehicles, lilliputian spies so tiny they can take off and land in the palm of their operators' hands. The U.S., Great Britain, Korea, and Israel are developing MAVs for surveillance use in the future.

BLACK WIDOW (USA) →

SPIES THAT FLY

Spy Photos
Surveillance photographs of Kosovo, Iraq, and other hotspots.

Master of the Surveillance Image
Meet former CIA photo analyst Dino Brugioni.

Time Line of UAVs
Explore the history of unmanned aerial vehicles.

Imaging With Radar
What can synthetic aperture radar "see"?

SEND FEEDBACK

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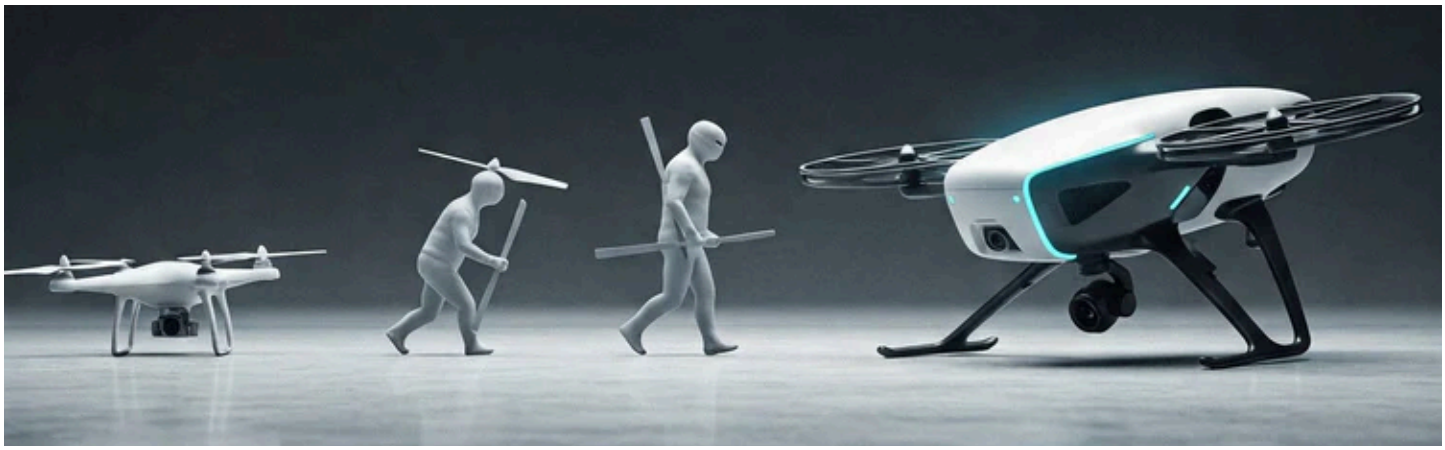
The Evolution of Drones: From Origins to the Future of Flight

SEPTEMBER 12, 2025



Share

Editor: This article was updated in 2025 to reflect the latest advancements in drone technology, including AI autonomy, extended endurance solutions, new FAA regulations, and current market growth forecasts.

Drones didn't just take off overnight. What started as bulky prototypes has evolved into high-precision UAVs transforming industries worldwide. From military origins to AI-driven, autonomous systems, drones now power search-and-rescue, industrial inspections, and precision agriculture.

If you're still treating drones as just "flying cameras," you're missing the point. These machines now handle life-saving search-and-rescue missions, high-stakes infrastructure monitoring, and precision agriculture—all with capabilities once thought impossible.

What's next? Smarter AI, longer flights, and deeper enterprise integrations. The industry isn't slowing down—neither should you. Dive in, because the next chapter of UAV innovation is already being written.

The Sky’s No Longer the Limit

Drones are evolving at an unprecedented pace. What started as military surveillance tools has expanded into industries like agriculture, search and rescue, filmmaking, and logistics. As 2025 approaches, the next wave of drone technology promises to push boundaries even further.

Understanding these advancements is crucial for professionals across various industries. Whether you’re a filmmaker looking for next-level cinematography, an enterprise user seeking automation, or a first responder relying on UAVs for safety, knowing what’s next ensures you stay ahead of the curve.

This article breaks down the most exciting drone innovations coming in 2025, from AI-driven autonomy to next-generation power sources and regulatory shifts that will change how drones integrate into our daily lives.

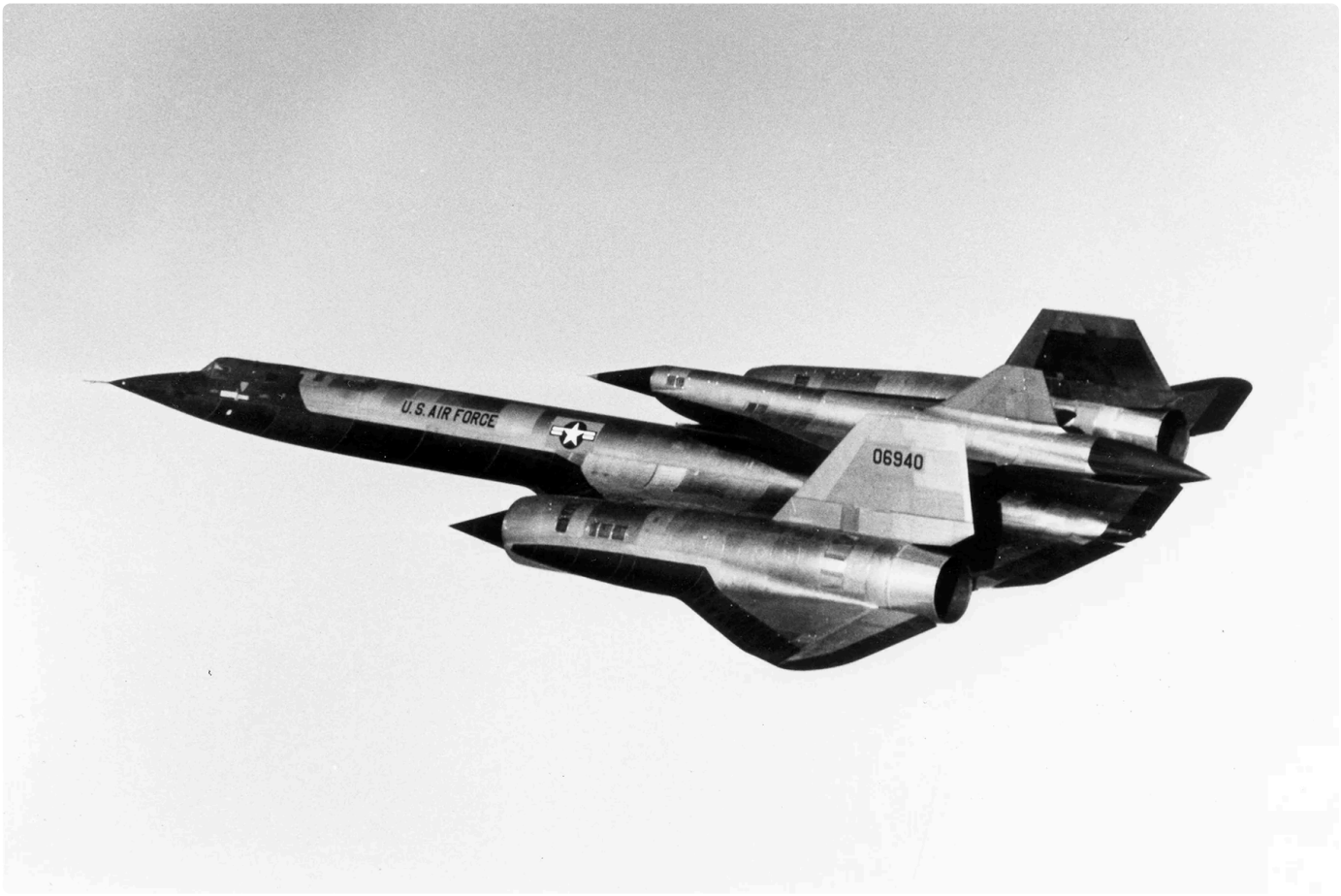
The Origins: How Drones Took Flight

Drones didn’t start as sleek, high-tech UAVs. Early models were crude, experimental machines built for military reconnaissance. World War I saw the first pilotless aircraft, and by the mid-20th century, drones were reshaping defense strategies.

It wasn’t until the 2000s that drone technology broke into commercial and consumer markets. Miniaturization, GPS, and smarter automation turned UAVs into game-changers for photography, agriculture, and industrial operations. What began as military tools are now indispensable across industries—and this is just the beginning.

A. The Early Days: Military Beginnings

Drones weren’t always consumer gadgets; their origins lie in military applications designed for reconnaissance and intelligence gathering. Initially developed as uncrewed aerial vehicles (UAVs) for battlefield support, these early prototypes paved the way for today’s sophisticated drone technology.



The Lockheed D-21

- **World War I & II:** The first UAVs emerged as experimental tools for battlefield intelligence. While they lacked precision and reliability, they demonstrated the potential of uncrewed aircraft in military strategy.
- **Cold War Advancements:** High-speed reconnaissance drones like Lockheed's D-21 became crucial for intelligence missions, reducing the need for manned spy aircraft in high-risk zones.
- **1990s Predator Drones:** The U.S. military revolutionized UAV capabilities with the introduction of remotely piloted Predator drones, equipped with advanced surveillance and combat functionality.
- **2020s Modern Conflicts:** Recent wars in Ukraine and the Middle East have shown how drones, ranging from commercial quadcopters to loitering munitions, are central to modern battlefields. They are used for reconnaissance, precision strikes, and electronic warfare, while driving rapid innovation in counter-drone systems to detect, jam, or neutralize UAV threats.

These iterations, from Predator to present-day tactical drones, laid the foundation for UAVs to transition from classified military tools to mainstream civilian and enterprise applications.

B. Breaking into the Civilian Market

The commercial drone revolution took off in the early 2000s, shifting UAVs from military exclusivity to mainstream accessibility. Rapid advancements in stabilization, imaging, and automation made drones viable for recreational and professional use.

- **2000s: The Rise of Consumer Drones**
  - DJI's Phantom series set the standard for user-friendly drones, making aerial photography and videography widely accessible.
  - Improved GPS stabilization and first-person view (FPV) technology transformed UAV usability for hobbyists and professionals alike.
- **2010s: The Drone Boom**
  - FAA regulations began shaping the commercial drone landscape, legitimizing UAV operations in various industries.
  - Cinematic drones dominated Hollywood, enhancing productions such as Game of Thrones, James Bond, and live event broadcasting.
  - Enterprise drone applications expanded into agriculture, security, and infrastructure inspections, proving UAVs' value beyond entertainment.
- **2020s: Commercial Expansion**
  - Drones became indispensable tools in industries like public safety, construction, and logistics, integrating seamlessly into workflows.
  - The rise of autonomous delivery drones and AI-driven UAVs expanded their functionality, demonstrating their role in the future of automation.

The journey from military surveillance tools to essential assets in creative, industrial, and emergency response sectors showcases the remarkable evolution of drone technology.

Looking Ahead: The Future of Drone Technology

Drone innovation isn't slowing—it's accelerating. AI-powered automation, extended flight endurance, and advanced data analytics are redefining what UAVs can do. From autonomous deliveries to next-gen industrial applications, the boundaries are expanding fast.

Staying ahead means embracing the evolution. Whether you're a drone professional or an enterprise looking to scale operations, now is the time to invest in cutting-edge UAV technology. The future of drones isn't coming—it's already here. Are you ready to keep up?

Where We Stand: Drones Today

Drones have advanced beyond simple aerial photography. With AI integration, extended flight endurance, and regulatory adaptations, they are reshaping industries from agriculture to emergency response. The technological leap in drone capabilities has

unlocked new possibilities, making UAVs indispensable tools across various professional fields.

A. Game-Changing Features Defining Modern Drones

Modern drones integrate cutting-edge innovations that enhance safety, intelligence, and efficiency in every operation:

- **AI-Powered Navigation**
  - Real-time object detection and avoidance for autonomous flight in dynamic environments.
  - Machine learning algorithms optimize flight paths, reducing pilot workload and increasing mission success rates.
- **Longer Flight Times**
  - Enterprise drones now routinely fly 60–70 minutes on advanced lithium batteries, while hydrogen fuel cell platforms extend missions to several hours.
  - Solar-assisted UAVs and automated battery swap stations are also in use, supporting near-continuous operation for inspections, security, and emergency response.

- **BVLOS (Beyond Visual Line of Sight) Approvals**
  - FAA rulemaking has advanced with the Part 108 BVLOS proposal and full Remote ID enforcement, setting the stage for routine long-range operations.
  - Drones are now cleared for missions such as package delivery, utility corridor inspections, and public safety patrols, eliminating the need for visual observers.

- **LiDAR & Thermal Imaging**
  - LiDAR-equipped drones capture high-resolution topographical data, essential for mapping and land surveys.
  - Thermal cameras enhance firefighting, search-and-rescue, and hazardous material detection by identifying heat sources and temperature variations.

- **Swarm Technology**
  - Multiple UAVs coordinate in synchronized formations for complex tasks in agriculture, military defense, and environmental monitoring.
  - Swarm applications include automated field spraying, military reconnaissance, and large-scale infrastructure assessments.

B. Industries Leading the Drone Revolution

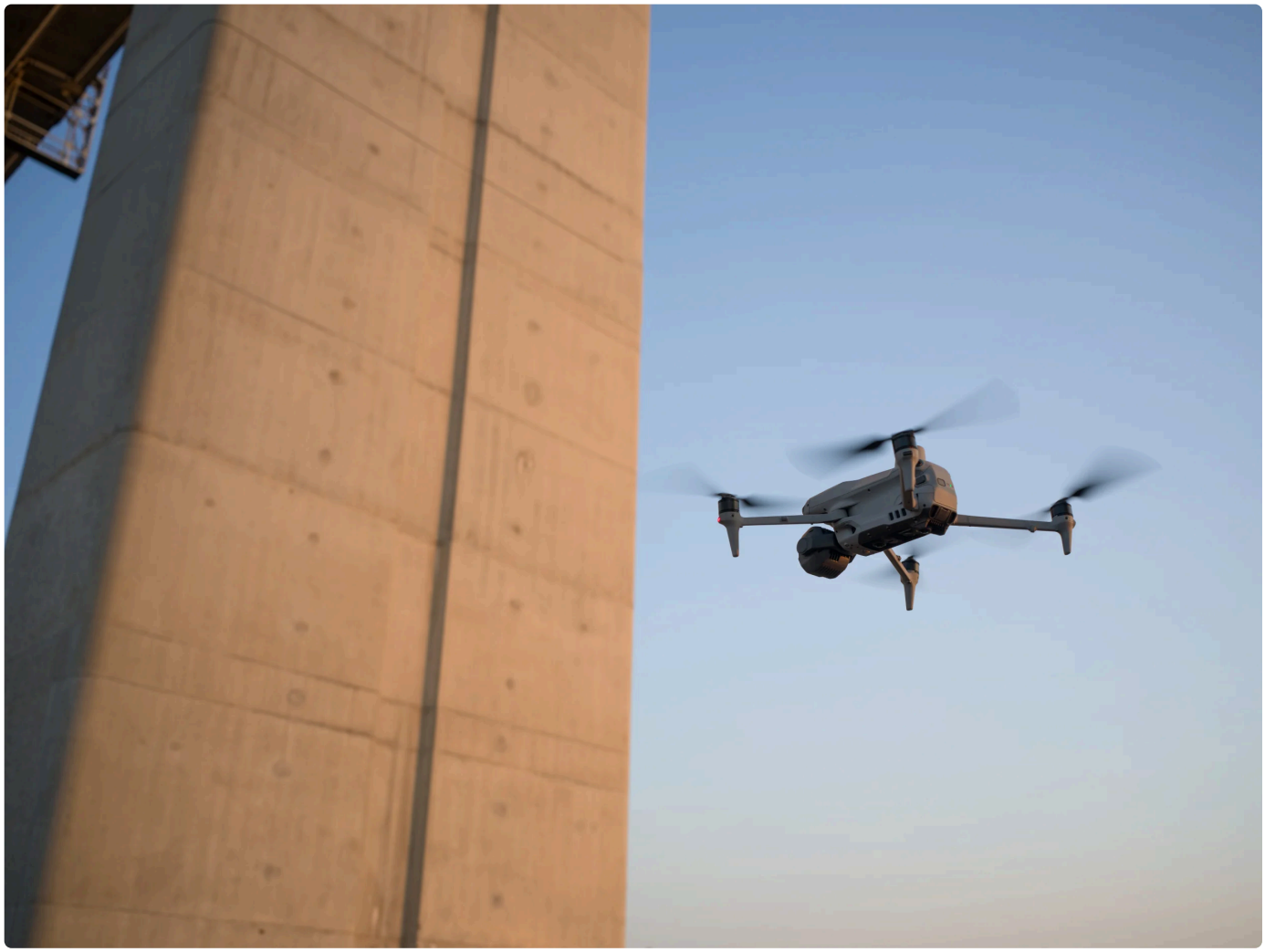
Across various sectors, drones continue to revolutionize workflows, reduce costs, and enhance operational efficiency:

1. Public Safety

- Law enforcement agencies now integrate drones with autonomous docking stations for rapid deployment in crowd control, suspect tracking, and crime scene analysis.
- Firefighters rely on UAVs equipped with thermal imaging and AI analytics to identify hotspots, predict fire behavior, and improve on-the-ground strategy.
- Disaster response teams use long-endurance drones for search-and-rescue, infrastructure assessment, and supply delivery, often coordinating with BVLOS operations to cover larger areas without direct line of sight.

2. Agriculture

- AI-powered drones equipped with multispectral and hyperspectral sensors now deliver real-time crop health analysis, helping farmers optimize water, fertilizer, and pesticide use with greater precision.
- Automated spraying drones such as the DJI Agras T50/T60 execute large-scale treatments, reducing chemical waste while improving yield efficiency.
- Farmers increasingly rely on UAV-generated data for soil mapping, irrigation planning, and predictive analytics, turning drones into essential tools for sustainable farming.



3. Infrastructure & Construction

- UAVs now perform BVLOS corridor inspections and structural assessments on bridges, towers, and industrial sites, reducing the need for crews in hazardous environments.
- AI-enabled 3D mapping drones generate highly detailed digital twins, improving project planning, monitoring, and predictive maintenance.
- Automated aerial surveys, combined with real-time data streaming, ensure compliance with construction timelines, safety protocols, and regulatory reporting.

4. Cinematography

- High-end drones capture 8K RAW footage and dynamic aerial shots for blockbuster films, documentaries, and commercial productions.
- First Person View or FPV drones are now mainstream in sports, commercials, and streaming content, adding immersive, high-speed perspectives once impossible with traditional rigs.
- Live broadcasting integrates drone footage for major events, while VR and AR-ready drones create interactive experiences in tourism, gaming, and virtual production studios.

The Present Defines the Future

With AI-driven automation, expanded flight capabilities, and regulatory progress, drones continue to push technological boundaries. The industries that embrace UAV advancements gain a competitive edge, streamlining operations and enhancing efficiency. As innovation accelerates, the role of drones in everyday applications will only expand further.

What’s Next: Drone Trends 2025 and Beyond

The drone industry is on the brink of another major transformation. In 2025, cutting-edge advancements in AI, power efficiency, and regulatory frameworks will push UAV capabilities beyond current limitations. From drones that operate independently with real-time AI decision-making to hydrogen-powered UAVs capable of hours-long flights, these innovations will define the next era of drone technology.

For professionals across public safety, agriculture, infrastructure, and logistics, staying ahead of these developments isn’t optional—it’s essential for maintaining operational efficiency, compliance, and competitive edge. Let’s explore the trends set to reshape the drone landscape in 2025 and beyond.

A. AI-Driven Autonomy & Smart Drones

Automation is no longer just a feature—it's becoming the standard. The next generation of drones will integrate advanced AI decision-making, reducing human intervention while improving efficiency, accuracy, and real-time responsiveness.

Key Innovations in AI-Powered UAVs:

✔ **Full Automation: Decision-Making Without Human Input**

- AI-powered UAVs now analyze surroundings, detect obstacles, and adjust flight paths in real time with minimal oversight.
- Operators focus on mission planning and data review, while drones execute flights autonomously, even in complex environments.
- This capability is increasingly deployed in search and rescue, industrial inspections, and security surveillance.

✔ **Self-Charging Stations: Continuous Operation Without Downtime**

- Automated docking stations allow UAVs to land, recharge, or swap batteries before resuming missions.
- Critical for 24/7 surveillance, disaster monitoring, and industrial inspections that demand constant coverage.
- Fleet systems manage rotations seamlessly, ensuring near-continuous operation without human intervention.

✔ **Edge AI Processing: Faster, Smarter, More Efficient**

- Onboard edge computing delivers split-second analytics for mapping, object recognition, and tracking without relying on cloud connectivity.
- Swarm-capable drones now collaborate in coordinated formations, handling tasks like precision agriculture spraying, wide-area monitoring, and multi-angle inspections.
- This combination of edge AI and swarm intelligence is redefining autonomy, making UAV fleets faster, smarter, and more responsive.

The Impact: AI-driven autonomy will redefine drone operations, making UAVs self-sufficient, highly responsive, and capable of handling complex missions with minimal oversight.

B. Extended Flight & Power Innovations

Current battery limitations cap drone flight times, but that's about to change. 2025 will introduce next-generation power solutions that extend endurance, improve sustainability, and reduce operational downtime.

Breakthroughs in Drone Power Systems:

✔ **Hydrogen Fuel Cells: Breaking the Multi-Hour Barrier**

- Modern hydrogen-powered drones now sustain flights for three to six hours, making them standard in long-range industrial, military, and delivery missions.

- Zero-emission operation also aligns with global sustainability and defense logistics goals.

✔ **Solar-Powered Drones: Multi-Day Aerial Coverage**

- High-efficiency solar UAVs achieve multi-day endurance, already in use for environmental monitoring, border patrol, and disaster response.
- These systems reduce reliance on conventional charging, offering low-cost and sustainable aerial coverage.

✔ **Battery Swap Tech: Instant Power Replacement**

- Automated swap stations and dock-based recharging hubs support near-continuous drone operation in the field.
- This capability is now widely deployed in public safety, infrastructure monitoring, and industrial inspection fleets, reducing downtime and extending mission coverage.
- By minimizing battery degradation, docking systems also cut long-term maintenance costs.

The Impact: Longer flight times mean fewer disruptions, higher efficiency, and reduced operational costs—essential for enterprise drone users needing extended aerial coverage.

C. Expanding Regulatory Approvals & Commercial Growth

As drone technology advances, global aviation authorities are easing restrictions to allow broader commercial UAV use. Expect major policy shifts in 2025 that will unlock new drone applications in logistics, security, and urban transportation.

Key Regulatory and Market Advancements:

✔ Wider BVLOS Authorizations: Unlocking Long-Distance Operations

- With the FAA's Part 108 BVLOS proposal and full Remote ID enforcement, drones are cleared for routine long-distance operations.
- This shift accelerates package delivery, large-scale agricultural monitoring, and public safety patrols.
- Visual observers are no longer required for many enterprise missions, reducing costs and expanding deployment flexibility.

✔ Urban Air Mobility (UAM): Passenger Drones Enter Reality

- Pilot programs for passenger drones and flying taxis are already underway in cities worldwide.
- CCompanies like Joby Aviation, Archer, and EHang are conducting flight trials with eVTOL aircraft, moving urban aerial transport closer to certified service.
- Regulators are finalizing airspace management frameworks to integrate autonomous passenger drones into city environments safely.

✔ **5G-Connected UAVs: Faster, Lag-Free Aerial Data Transmission**

- 5G networks now enable real-time, high-speed drone communications for fleet coordination, remote inspections, and live broadcasting.
- In parallel, satellite connectivity (e.g., Starlink, OneWeb) is being integrated into UAV operations, extending coverage to remote regions.
- This hybrid communication model ensures reliability for emergency response, infrastructure monitoring, and BVLOS operations far from populated areas.

The Impact: Regulatory progress and new connectivity standards are fueling a drone-powered economy that continues to expand across logistics, agriculture, construction, and public safety. Industry reports project the global drone market will surpass USD 54 billion in 2025, with heavy-lift, AI-enabled, and sector-specific UAVs driving the next wave of growth.

AI-driven autonomy, next-gen power solutions, and expanding regulations are set to push drones further into logistics, public safety, and even passenger transport. For businesses, adapting isn't optional—it's the key to staying ahead.

Should You Upgrade? How Drone Technology Evolution Affects You

The drone industry is advancing at an unprecedented pace, with 2025 marking a turning point in UAV capabilities. Professionals relying on drones for industrial, creative, and emergency applications must evaluate whether their current fleet is keeping up with innovation or falling behind in efficiency and capability.

Upgrading isn't just about staying competitive—it's about unlocking greater automation, enhanced imaging, improved safety features, and longer flight times. Whether you need drones for precision mapping, cinematic filmmaking, or life-saving emergency response, new-generation UAVs offer tools that make missions faster, smarter, and more reliable.

So, who needs to stay ahead? And what's the best upgrade path?

A. Who Needs to Keep Up?

Not all industries evolve at the same pace, but in drone technology, lagging behind can mean lost efficiency, higher costs, and reduced effectiveness. Here's who should consider upgrading in 2025:

1. Industrial Operators: Precision & Automation Matter More Than Ever

For industries like construction, infrastructure inspection, energy, and agriculture, accuracy and efficiency define success. Older drones lack the automated data collection, AI-driven analytics, and sensor integrations that today's enterprise UAVs provide.

Why Upgrade?

- **More Accurate Data Collection** – AI-powered mapping, LiDAR scanning, and thermal imaging refine survey results.
- **Increased Efficiency** – Autonomous flight modes cut down on manual piloting, reducing labor and operational time.
- **Better Safety & Compliance** – Next-gen drones have improved collision avoidance, regulatory compliance features, and enhanced security protocols.

✔ **Recommended Upgrades:** Matrice 4T, DJI Dock, Autel Evo Max

2. Filmmakers & Content Creators: Elevate Cinematic Storytelling

Aerial cinematography is no longer just about getting the shot—it's about capturing dynamic, high-resolution footage with minimal effort. AI tracking, FPV capabilities, and enhanced stabilization are now standard in high-end drone filmmaking.

Why Upgrade?

- **AI-Assisted Tracking** – Auto-follow subjects with unmatched precision.
- **Pro-Grade Cinematic Cameras** – 8K RAW, HDR, and variable aperture options for professional shoots.
- **Advanced Flight Controls** – Execute complex aerial maneuvers with precision—no need for a secondary operator.

✔ **Recommended Upgrades:** DJI Inspire 3, Mavic 3 Pro Cine

3.Emergency Responders: Faster, Smarter, More Reliable Drones Save Lives

In search & rescue, law enforcement, and firefighting, every second counts. Older drones lack thermal imaging accuracy, extended flight endurance, and real-time situational awareness tools that today's mission-critical UAVs deliver.

Why Upgrade?

- **Longer Flight Times** – More air coverage means fewer delays in critical situations.
- **Better Low-Light & Thermal Vision** – Pinpoint heat signatures in collapsed buildings, dense forests, or urban disasters.
- **Quicker Deployment** – Compact, rugged, ready-to-fly drones designed for rapid emergency response.

✔ **Recommended Upgrades:** Matrice 350 RTK, DJI M30T

B. Future-Proofing Your Drone Fleet

Technology is evolving rapidly—sticking with outdated drones means missing out on new efficiencies, features, and industry advancements. Before making an upgrade, evaluate your current fleet and determine whether your drones are meeting mission requirements.

1. Assess Your Current Setup

✔ **Are your drones missing key features?** (AI automation, obstacle avoidance, long-range transmission)
✔ **Is battery life limiting your operations?** (Newer models have extended flight capabilities)
✔ **Are your sensors outdated? (**Upgraded cameras, LiDAR, and thermal imaging make a difference)
✔ **Are you struggling with compliance?** (Modern drones come with regulatory-ready data encryption and tracking tools)

If yes to any of the above, it's time to invest in a next-generation drone.

2. Choosing the Right Upgrade

Best for Industrial & Enterprise:

- Matrice 4T – Advanced payloads, AI processing, and LiDAR capabilities.
- DJI Dock – Ideal for autonomous monitoring & surveillance.
- Autel Evo Max – Long-range communication, rugged durability.

Best for Public Safety & Emergency Response:

- Matrice 350 RTK – Robust, highly adaptable for police, SAR, and firefighting.
- DJI M30T – Lightweight, fast deployment, thermal imaging for rescue missions.

Best for Content Creation & Cinematography:

- DJI Inspire 3 – 8K ProRes, dual-camera setup, best for commercial filmmakers.

- Mavic 3 Pro Cine – Hasselblad camera, Apple ProRes recording, perfect for prosumers.

Staying Ahead in the Drone Industry

Drone technology isn't slowing down—it's accelerating. Staying competitive means adopting AI-powered automation, extended flight capabilities, and cutting-edge imaging that redefine professional drone applications.

If your fleet is falling behind, it's time to invest in the future of UAVs. Whether you need longer endurance, better imaging, or increased automation, today's upgrades will maximize efficiency, safety, and performance.

Ready to upgrade? Explore the latest drones at Dronefly.com, or consult with our UAV experts to find the perfect solution for your needs.

The Future of Drones Is Now

Drone technology has evolved from basic remote-controlled aircraft to highly intelligent, autonomous systems that integrate AI, machine learning, and advanced sensors. This transformation has revolutionized industries, from public safety and construction to agriculture and filmmaking. As we enter 2025, the next wave of UAV innovation will push boundaries further, introducing fully autonomous flight, real-time AI processing, extended battery life, and expanded regulatory approvals.

Why Staying Ahead Matters

1. **AI and Automation Will Lead the Way**
   Drones are no longer simple remote-controlled tools; they are becoming self-sufficient, data-driven machines. AI-powered navigation, obstacle avoidance, and real-time decision-making will significantly reduce pilot workload and improve operational efficiency.
2. **Advanced Sensors Will Redefine Capabilities**
   From thermal imaging and LiDAR mapping to edge AI processing, next-gen drones will offer unmatched accuracy and data collection capabilities. These features will enhance infrastructure inspections, public safety missions, and industrial applications, making drones more valuable than ever.
3. **Regulatory Approvals Will Shape the Industry**
   Governments and aviation authorities are working towards expanding BVLOS (Beyond Visual Line of Sight) operations and integrating UAVs into controlled airspace. Wider approvals will unlock new commercial drone applications, including delivery services, urban air mobility, and automated monitoring systems.

4. **Longer Flight Times and Better Power Solutions**
Battery limitations have been a major roadblock in drone evolution. Hydrogen fuel cells, solar-powered UAVs, and rapid battery swap technology are set to extend flight endurance and minimize downtime.

What This Means for You

✔ **Enterprise & Industrial Users:** Boost operational efficiency with drones that automate inspections, reduce human intervention, and provide real-time insights.

✔ Public Safety & Emergency Responders: **Deploy faster and respond smarter with UAVs** that offer thermal imaging, AI-assisted tracking, and extended flight times.

✔ **Filmmakers & Content Creators**: Capture more, create more—harness high-resolution imaging, AI subject tracking, and FPV drone cinematography for unparalleled aerial footage.

✔ **Hobbyists & Enthusiasts:** Access professional-grade features at a consumer level, from better stabilization and obstacle avoidance to AI-assisted flight planning.

The Time to Upgrade is Now

The drone industry is advancing at record speed, with AI-driven autonomy, dock-based deployment, and NDAA-compliant platforms setting new standards across every sector. Those who delay upgrades risk losing efficiency, compliance readiness, and a competitive edge. Whether your mission demands extended endurance, automated inspections, or next-level creative imaging, today's UAVs deliver tools built for 2025 and beyond.

Ready to adapt?
Explore the latest UAV models at Dronefly or consult with our experts to build a solution tailored to your mission. Stay ahead, stay innovative, and push the limits of what's possible.

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Quadrone: Propelling the Future of Autonomous Drone Delivery Systems

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Abstract:

This article investigates the uptake of drone delivery services in emerging economies, examining factors such as personal innovativeness, outcome expectancy, emotions, and perceived risk. Drone delivery offers advantages such as flexibility, accessibility, speed, safety, and environmental benefits. It conducts a comprehensive review of existing literature, identifies current trends and challenges, and proposes avenues for future research. Businesses are increasingly exploring autonomous solutions for the last-mile delivery to remain competitive and fulfill rising delivery demands. Drones, especially unmanned aerial vehicles, emerge as a promising solution in the realm of logistics. Recent regulations introduced by the Flight World Organization support the operation of unmanned aerial systems, further facilitating their integration into delivery operations. The surge in online shopping has intensified the need for efficient delivery mechanisms, thus driving the adoption of drone technology. Quadcopters, equipped with stable flight capabilities, are employed for various purposes including surveillance, data gathering, and localized deliveries. The integration of delivery drones into the last-mile shipping industry holds the promise of expedited deliveries, decreased labor expenses, and advantages for drone manufacturers, signifying a transformative shift in the realm of logistics and delivery services.

Key Words: Drone delivery services, Emerging economies, Personal innovativeness, Outcome expectancy, Perceived risk, Flexibility, Quadcopters, Logistics.

1. INTRODUCTION:

Originally, drones or unmanned aerial vehicles were initially developed for military purposes, as they could be operated remotely, thus minimizing the risk to pilots in combat situations [1]. However, in recent years, drones have found application across various industries due to their versatility, portability, light weight, and affordability compared to conventional aircraft. They play pivotal roles in fields such as mapping, photography, agriculture, and mining [2]. Moreover, enthusiasts continuously explore novel drone designs and functionalities for activities like racing, aerial photography, and recreational flying, delivery services attracted by the vast range of options and customization available.

In this article of we have expressed a need for the design, development, and prototyping of a autonomous drone capable of both flying automatically . The aim of this endeavor is to develop a unique drone prototype with distinctive features, tailored for commercialization in diverse markets. This involves designing a drone model that stands out from existing options and aligns with market demands, ensuring its viability for widespread adoption and commercial success.

This innovative concept, yet to be widely adopted, introduces a new dimension of flexibility and functionality to the drone landscape. By optimizing power consumption and extending the drone's battery life, this autonomous drone model offers numerous advantages. Moreover, it enhances maneuverability, particularly in areas where aerial navigation may be restricted or challenging.

2. SYSTEM ARCHITECHTURE:

Drone delivery systems are pivotal components within a broader system architecture, characterized by their intricate operational workflow and integration of advanced technologies. This section delineates the key stages and functionalities of drone delivery systems within the overarching system framework:

Order Processing and Packaging: At the outset, orders are received and processed within the system. Upon confirmation, items are meticulously packaged at the nearest warehouse, ensuring secure transportation for subsequent stages.

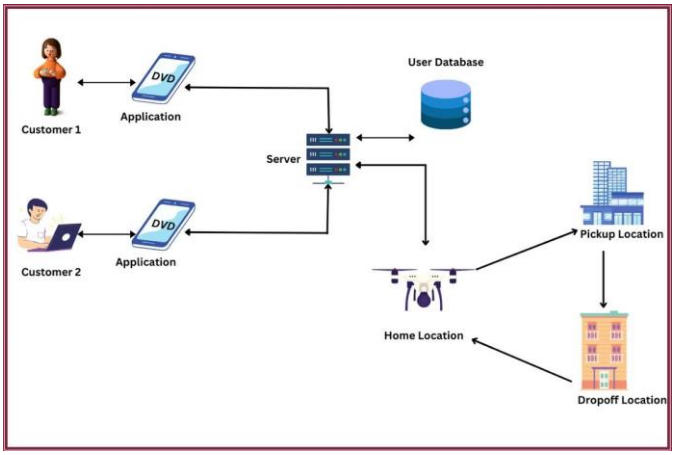

Figure 1: System Architecture

Customer Application: The DVD Delivery via Drone application offers several key features to enhance the customer experience:
1.Package Details Input: Users can input the weight of their package and specify the source and destination addresses.
2.Payment Options: The application supports various payment methods, providing users with flexibility and convenience.
3.Real-time Order Tracking: An integrated map feature allows users to track their orders in real-time, providing visibility into the delivery process.
4.Seamless User Interface: The application boasts an intuitive and user-friendly interface, making it easy for customers to place and manage their orders.
5.Enhanced Security: Robust security measures are implemented to safeguard user information and ensure the integrity of transactions.

Server : The server acts as the central hub where all data processing and communication between the application and users take place, while the user database stores and manages user information securely. The server architecture is designed to handle a high volume of requests and facilitate real-time communication between the application interface and the database. It utilizes robust hardware and software components to ensure optimal performance and reliability. Additionally, the server implements encryption protocols and access controls to safeguard sensitive data and protect against unauthorized access or cyber threats.

User Database: The user database stores various types of information, including user profiles, package details, delivery preferences, and transaction records. Each user profile is associated with a unique identifier, allowing for personalized experiences and streamlined order management. The database employs data normalization techniques to optimize storage efficiency and ensure data integrity, reducing redundancy and minimizing the risk of inconsistencies. Furthermore, the user database incorporates advanced security measures such as encryption, hashing, and role-based access control to protect user data from breaches or unauthorized access.

Departure Management: Following packaging, the system coordinates the departure of drones from the warehouse. This involves securely fastening packages to specialized carriers designed for drone transportation. Notably, drones employ a range of departure mechanisms, including VTOL (Vertical Takeoff and Landing) processes or innovative designs like non-VTOL crafts, depending on the system configuration.

Pickup and Dropoff : At the source location, the drone lands or hovers at a predetermined spot to collect the package. This may involve a designated landing pad or an area cleared for drone operation. Alternatively, the package may be placed in a secure container or docking station for pickup by the drone. The drone takes off and begins its flight to the destination address. It follows a pre-programmed flight path or real-time instructions from a remote operator, avoiding obstacles and adhering to airspace regulations. After completing the delivery, the drone may return to its base or proceed to the next delivery location, depending on the operational requirements and scheduling.

3. LITEATURE SURVEY:

Title: Autonomous Drone Delivery to Your Door and Yard

Authors: Shyam Sundar Kannan and Byung-Cheol Min

Published: 2022

In this study, we introduce a novel system for delivery drones to autonomously navigate and deliver packages within residential areas without relying on external markers. This advancement is driven by recent progress in deep learning, which has the potential to replace specialized markers used by drones. Our system takes delivery instructions as input, akin to instructions given to human couriers. Initially, we propose a semantic image segmentation-based method to estimate suitable landing spots around the house. Subsequently, we devise a routing strategy to guide the drone from the landing spot to the desired delivery location, such as the front door. Through extensive simulation, we demonstrate the effectiveness of our approach, showing significant time savings compared to traditional frontier exploration-based strategies.[1]

Title: Drone-Aided Delivery Methods, Challenge, and the Future: A Methodological Review

Authors: Xueping Li, Jose Tupayachi, Aliza Sharmin, Madelaine Martinez Ferguson

Published: 2023

Origin : Department of Industrial and Systems Engineering, University of Tennessee, Knoxville, TN 37996, USA

Drone delivery, or UAV delivery, has emerged as a promising alternative to conventional methods, offering unparalleled advantages such as flexibility, speed, efficiency, and safety. This paper conducts a systematic review of existing literature in this field, categorizing it based on problem characteristics and objectives. Through this analysis, we identify critical challenges spanning technological advancements, safety concerns, societal implications, and environmental impacts. By recognizing these hurdles, we aim to pave the way for future research directions that address these complexities and propel the development of drone delivery systems.[2]

Title DecentraliDrone: A decentralized, fully autonomous drone delivery system for reliable, efficient transport of goods

Authors: A. Sheik Abdullah, Abdul Aziz A.B, S. Geetha

Published: 2024

Origin : School of Computer Science and Engineering, Vellore Institute of Technology - Chennai Campus, Chennai 600127, Tamil Nadu, India

DecentraliDrone is an autonomous drone delivery system designed to meet the increasing demand for efficient and reliable delivery services in our interconnected world. Operating without human intervention, it ensures 24/7 service and minimizes accidents caused by human error. Its decentralized structure, relying on a network of drones and devices, enables scalability and adaptability to changing demands. Challenges include developing robust communication protocols, ensuring system safety and security, and navigating regulatory hurdles. Overcoming these challenges is essential for DecentraliDrone to realize its potential in revolutionizing the delivery industry, offering a seamless, efficient, and autonomous solution to meet the evolving needs of global commerce.[3]

Title : Autonomous Quadcopter for Product Home Delivery

Authors: Md R Haque, M Muhammad, D Swarnaker, M Arifuzzaman

Published: 2016

Origin : Lecturer and Students at Department of Aeronautical Engineering Military Institute of Science and Technology Dhaka, Bangladesh
This study introduces a cost-effective Quadcopter (QC) as a lightweight autonomous Unmanned Aerial Vehicle (UAV) designed for delivering online-ordered parcels.

Utilizing an Android device as its central processing unit, the QC navigates to destinations using Google Maps. The paper showcases successful parcel deliveries and return trips to the starting point, indicating potential for further exploration of QC parcel delivery applications.[4]

Title : Designing autonomous drone for food delivery in Gazebo/Ros based environments

Authors: Hrishitva Patel

Published: 2022

Origin : Watson school of engineering(State University of New York, Binghamton)

Binghamton, New York
"Meeting the demand for swift and convenient delivery services, especially amid the COVID-19 pandemic, drives the need for innovative solutions. Our paper introduces a novel navigation system for efficient food parcel delivery using independent drones. Leveraging LiDAR sensors, it autonomously plans routes, avoiding obstacles en route. Precision landing is ensured through marker-based guidance and advanced algorithms. Our approach promises to revolutionize delivery services, addressing global demands for accessibility and efficiency."[5]

Title : Autonomous Drone Delivery System

Authors: Prof. Shilpa M Satre, Roshan Chilap, Manish Ukirade, Darshan Badgujar

Published: 2019

Origin : Student, Information Technology, BVCOE, Navi Mumbai

A novel miniature quadcopter delivery system is introduced, utilizing cost-effective microcontrollers and components like Electronic Speed Controllers, Arduino UNO, US sensors, GPS, and others. This system autonomously delivers lightweight goods to user-specified destinations, minimizing human intervention. To address real-time obstacles, US sensors are incorporated for path avoidance. This technology facilitates swift deliveries, especially in urban settings with traffic congestion, and enables access to hard-to-reach areas. Its applications span online product delivery, postal services, agriculture, and rescue operations in hazardous environments.[6]

4. METHODOLOGY:

4.1 Algorithm:

Step 1: Order Placement:

User inputs pickup (A) and delivery (B) locations, package details.

Step 2: Verification & Payment:

System validates package details, user confirms order and pays.

Step 3: Drone Assignment:

System assigns suitable drone based on package, proximity to A.

Step 4: Package Pickup:

Drone navigates to A, authenticates, retrieves, and confirms pickup.

Step 5: Flight to Destination:

Drone follows designated path to B, monitored by the system.

Step 6: Package Delivery:

Drone reaches B, authenticates, and delivers the package.

Step 7: User Notification:

User receives confirmation of successful delivery.

Step 8: Order Updates:

System updates delivery status, may request user feedback.

Step 9: Drone Maintenance:

Drone returns for maintenance, charging, or future assignments.

4.2 Flowchart:

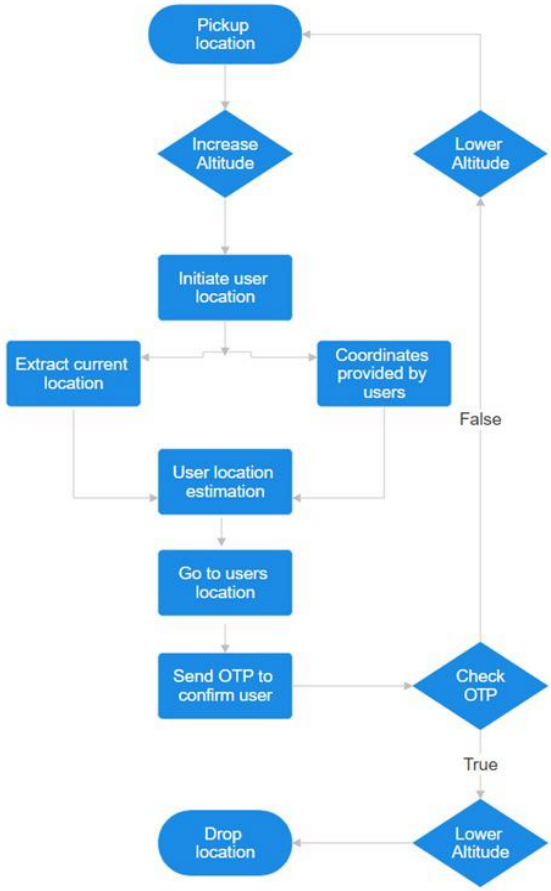

Figure 2: Flowchart

5. REQUIREMENTS:

5.1 Hardware Requirements:

1. Quadcopter: A quadcopter, also called quadrocopter, or quadrotor is a type of helicopter that has four rotors. They have the ability to hover in place whereas fixed wing aerial drones must be constantly moving.

2. Proximity Sensor: A proximity sensor is a device that can detect or sense the approach or presence of nearby objects and for this it does not need physical contact

3. GPS module: GPS module acts as a navigation and positioning system, providing crucial information to the pilot or flight control software.

4. Electronic Speed Controller: Electronic speed controllers (ESCs) are devices that allow drone flight controllers to control and adjust the speed of the aircraft's electric motors. A signal from the flight controller causes the ESC to raise or lower the voltage to the motor as required, thus changing the speed of the propeller.

5. Receivers: Drone receivers are essential hardware components responsible for receiving signals from various sources, such as remote controllers, GPS satellites, and other communication devices.

6. Motors: The motors in a drone are critical components responsible for generating thrust and controlling the movement of the aircraft.

7. Battery: The battery in a drone is a crucial component that provides the necessary power for the drone's operation.

8. Propellers: Propellers are a crucial component of drones, responsible for generating the thrust required for flight.

9.Jumper cables: Jumper cables in the context of a drone typically refer to a set of cables used for various purposes related to electrical connections within the drone or for external connections with other devices.

10. Arduino: Using an Arduino in a drone involves employing the Arduino microcontroller platform for various functions within the drone system. Using an Arduino in a drone involves employing the Arduino microcontroller platform for various functions within the drone system like Flight Controller, Sensor Integration, Motor Control, Wireless Communication, Payload Management, Safety Features, Customization and Expansion.

5.2 Software Requirements:

1. React Native: This framework allows you to build a cross-platform mobile app (iOS and Android) for controlling the drone.

2. JavaScript: The primary programming language for developing the app using React Native.

3. Communication Protocol: Implement the MAVLink communication protocol, which is commonly used for drone communication and control. It provides a standard way to send and receive commands and telemetry data.

4. Node.js: It is a JavaScript runtime built on Chrome's V8 JavaScript engine. It is used for server-side programming, and primarily deployed for non-blocking, event-driven servers, such as traditional web sites and back-end API services.

5.MongoDB: MongoDB is a popular NoSQL database management system that is widely used in various industries, including the drone industry.

6.Arduino: Arduino code can be used in drone development for various purposes, such as controlling flight dynamics, processing sensor data, implementing autonomous navigation algorithms, and interfacing with peripherals.

6. FULL IMPLEMENTATION:

The sign in page is where existing users authenticate themselves to access the app's features. It verifies user credentials, typically through a combination of email and password authentication, or more advanced methods like biometric recognition for enhanced security. Throughout this process, the focus remains on maintaining a balance between robust security measures and providing a seamless user experience.

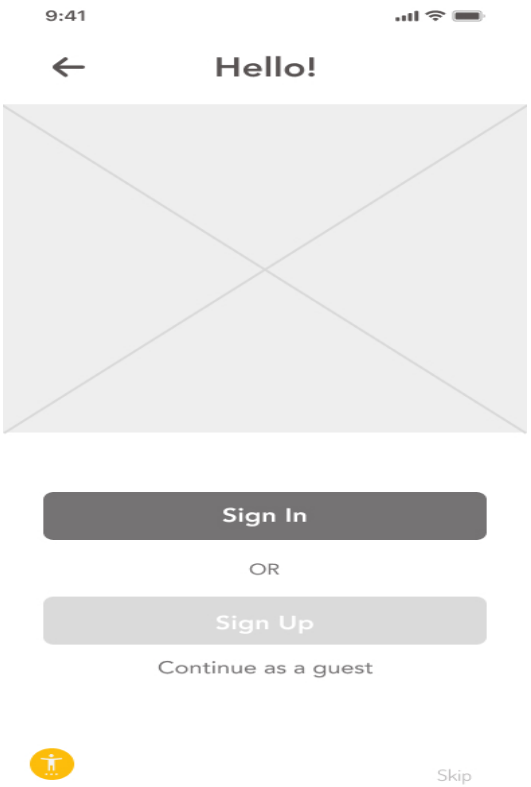

Figure 3: Sign In Page

The sign-up page of the drone delivery customer app serves as the entry point for new users, allowing them to register and create accounts. It prompts users to input necessary information such as their name, email address, and a secure password. This process ensures that accurate data is collected and stored securely, safeguarding user privacy and account integrity.

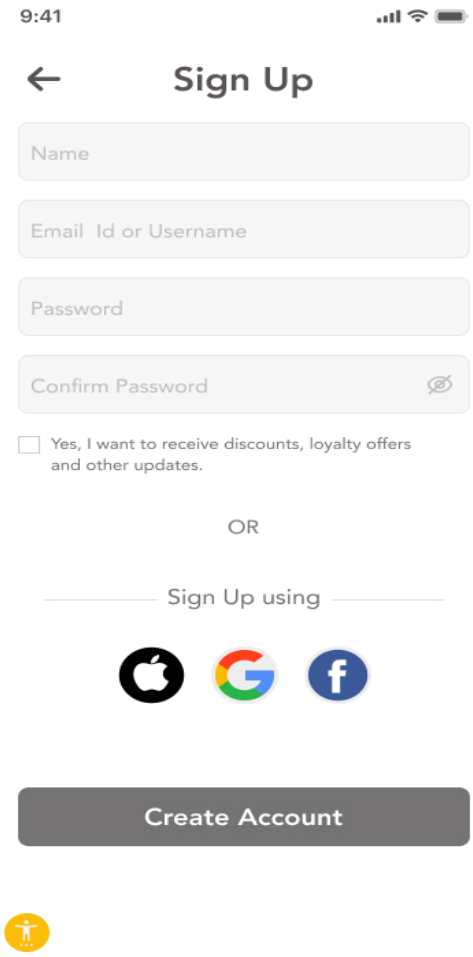

Figure 4: Sign Up Page

Here is the UI layout of our Drone application:

1. Home Screen:

- Logo of the delivery service/company.
- Navigation menu/button for different sections of the app.
- Option to start a new delivery request.

2. New Delivery Request Screen:

- Input field for the weight of the item (in kilograms or pounds).
- Input field for the distance from the initial point to the destination (in kilometers or miles).

- Button to confirm the details and proceed.

3. Delivery Details Confirmation Screen:

- Summary of the entered details (weight and distance).

- Button to confirm the details and proceed to the next step.

4. Delivery in Progress Screen:

- Real-time tracking of the delivery drone's location.

- Estimated time of arrival (ETA).

- Option to contact support or view delivery status.

5. Delivery Completed Screen:

- Confirmation message of successful delivery.

- Option to rate the delivery experience or provide feedback.

- Button to start a new delivery request.

7. CONCLUSION:

Drone delivery systems represent a groundbreaking shift in logistics, driven by advancements in IoT technology within the transportation sector. Their integration in emerging markets holds the potential to revolutionize the final stages of delivery, offering unmatched flexibility, speed, safety, and environmental advantages. From e-commerce to healthcare, these systems are fundamentally altering traditional delivery pathways. With our project nearing 70% completion, our primary goals are to enhance operational efficiency, decrease delivery times, and promote environmental sustainability. Through a focus on efficiency gains, cost reduction, and technological innovation, we aim to redefine the standards of convenience and sustainability within the logistics industry. This progress signifies a pivotal step forward in shaping the future landscape of delivery systems.

8. ACKNOWLEDGEMENT:

It gives us Great pleasure in presenting the preliminary project report on "Quadrone: Propelling the Future of Autonomous Drone Delivery Systems ".

We would like to take this opportunity to thank our internal guide Prof. Tushar Surwade and co-guide Prof. Vrushali Wankhede for giving us all the help and guidance we needed. We really are greatful to them. For the kind support. Their valuable insights were very helpful.

We are also grateful to Prof. Sagar Rajebhosale, Head of department, computer engineering branch at the Keystone School of Engineering, for his indispensable support and suggestions.

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AUTOMATION AEROSPACE

Drone Design Trends and Best Practices

Drone applications are expanding and maturing, leading to some noteworthy drone designs.

Tim Stevens
June 23, 2023

16 Min Read

GORODENKOFF/ISTOCK/GETTY IMAGES PLUS VIA GETTY IMAGES

In the United States, the drone market grew to $11.1 billion in 2022, expected to swell to $82.9 billion by 2032, according to Fact.MR. Globally, it's projected to hit $279 billion that year, a 25 percent compound annual growth rate.

That astounding success comes thanks to the explosion of drone use on multiple fronts. On the industrial side, drones are used to survey everything from construction to cattle, with research applications swelling as technologies increase and costs decrease.

Meanwhile, recreational drone use on the consumer side is following a similarly skyward trajectory. Easy-to-fly, pocket-sized drones with advanced auto-following features and 4K video capture are increasingly de rigueur for serious travelers and adventure hounds.

Finally, military drones continue to grow in sophistication and specialization as global battlefields demand more advanced solutions. Military applications make up roughly half of the U.S. drone market, according to Fact.MR. Commercial use takes up 34.6 percent, while consumer/civil drones cover the remaining 15.6 percent of the market.

As these varied drone applications mature, so, too, have patterns and design trends grown and solidified. Let's dig deeper on that topic.

Drone Definitions and Categories

First, a little clarification of terms. The name "unmanned aerial vehicle" or UAV is the formal term that many have used traditionally and continue to use for this class of device. However, as outlined comprehensively in a 2022 volume of the journal, *Drone Systems and Applications*, that term presents some problems.

The inclusion of a gendered word, "unmanned," is one strike against it, but alternative terms like "uncrewed" or "unoccupied" present other undesirable complications and implications. The journal asserts that the term "drone" is not only the most widely used but also the most accurate, and so that is the term we'll use here throughout.

Additionally, while there are numerous terrestrial and underwater drones in use today, by far the majority of development in the drone industry relates to aerial craft, so that will be our primary focus.

Within aerial drones, there are three primary categories.

Fixed-Wing Drones

The most basic and oldest form of drone, dating back to remotely piloted aircraft in WWI, is the fixed-wing drone. These drones use a shape similar to a traditional aircraft, allowing them to fly at higher speeds and longer ranges.

However, fixed-wing drones generally lack the ability to hover, are more difficult to fly, and require significant space to take off and land safely.

Single- and Multi-Rotor Drones

When most people think of a drone, they think of a modern, multi-rotor drone, often with four separate motors spinning four separate propellers.

However, single-rotor drones also exist, operating more like a traditional helicopter. Both offer vertical take-off and landing, or VTOL capability, meaning many can be launched directly out of the operator's hand. Additionally, the advanced flight control software in these drones makes them straightforward to pilot, also providing a stable platform for precise surveying or scanning.

But, this type of flight has higher energy demands, dictating shorter flight times and smaller payloads than a fixed-wing drone.

Multi-rotor drones can support logistics and transport.

Hybrid Drones

This type of drone offers many of the benefits of both types of drone design. A hybrid drone offers VTOL capability for easy launch but can transition from hovering like a multi-rotor drone to horizontal, fixed-wing flight.

"You have all sorts of competing companies that have figured out how to make a fixed wing drone take off and land vertically, either by tilting the profile of the propellers upwards or downwards during takeoff and landing and then tilting them forward for flight," Dr. Dominique Chabot told us. He's lead scientist at droneMetrics, a remote sensing and analytics company, adjunct professor at Trent University, and editor-in-chief at the journal, *Drone Systems and Applications*.

These drones offer many of the benefits of both types of drones, but do not offer the same efficiencies or speeds of a fixed-wing drone nor the extreme stability of a multi-rotor.

Common Drone Applications

Agriculture

Smart agriculture is an increasingly vital aspect of modern farming, particularly when it comes to food and feedstock supply. Drones can check soil moisture levels, monitor plant health and production, deploy fertilizers and pesticides, and even scout for pests and other interlopers.

The trend here is generally towards multi-rotor drones, like the DJI AGRAS T40, which can carry up to 50 kg of payload for precision spraying or spreading, enough to cover 52.6 acres (21.3 hectares) per hour.

But not all ag applications require hoppers or sprayers. The ZenaDrone is a four-rotor machine specifically designed for the unique requirements of monitoring hemp farms. "Because the drone records videos and captures images of the hemp plantation, the farmers also were able to predict plant health and resolve plant problems before they got worse," ZenaDrone founder and CEO Dr. Shaun Passley told us last year.

A utility drone spraying pesticide over a corn field.

Delivery

While the COVID pandemic imparted new importance to package and food delivery globally, drone delivery was already well under development. "In some parts of the world, particularly in Africa, this is already being done in areas that are sparsely populated or hard to reach," Dr. Jeremy Laliberte told us. He's a professor in mechanical and aerospace engineering and associate chair for lab operations and research at Carlton University. He's also program director for the NSERC CREATE Uninhabited aircraft systems Training, Innovation and Leadership Initiative (UTILI).

But, this technology is slowly spreading. Drone delivery start-up Zipline received FAA authorization for testing in the U.S., completing 6,000 drone deliveries here last year.

The need for carrying large payloads often calls for fixed-wing aircraft for delivery applications. However, some companies, like Amazon's Prime Air, are developing custom, hybrid drones offering VTOL capability in addition to extended flight times.

Media

Drone use in media has exploded in recent years, with drones serving as advanced, stabilized platforms for carrying video and photographic equipment. The rise in drone journalism has enabled real-time updates from difficult to reach or even hazardous situations, like war zones, protests, and natural disasters.

The trend of drone use has captured Hollywood, too, with more and more films featuring drone shots, even from first-person-view, or FPV drones, a type of highly maneuverable multi-rotor design. 2022's *Ambulance* by Michael Bay featured an extensive FPV sequence.

Military

Military use makes up half of the global drone market, with applications ranging from long-range explosive payload delivery to up close and personal battlefield surveillance.

This breadth of application means drones of all types, from fixed-wing drones the size of fully crewed aircraft to the Black Hornet, a single-rotor drone little bigger than its namesake.

Scientific Research

Drones now play a crucial role in many areas of scientific research thanks in large part to the increased availability and reduced cost of commercial drones.

Drone types vary depending on application. "When you want to do larger scale mapping projects, oftentimes fixed wing is the way to go just because they have longer flight endurance and can cover more area in less time," Dominique Chabot told us, who has been using drones in research since 2007. "Whereas, when you want to do those very precise [projects], obviously multirotors can do things fixed wing drones can such as take off and land vertically, and they can also hover or fly really slowly if needed."

Propulsion Types

While larger drones, particularly for military use, tend to rely on internal-combustion engines for flight, smaller models for commercial or personal use generally rely on electric propulsion. Of those, DC brushless motors continue to be the standard, thanks to their high efficiency and extended lifespans vs. brushed motors.

One extreme example is the Mars Ingenuity drone, which relies on both types of DC motors. "So, brushless motors are typically for longer life, higher use, higher speed," Jeff Randall told us. Randall is business development engineer for aerospace at maxon USA.

"But," he continued, "if you have something like a pan-and-tilt mechanism that may rotate 30 degrees and stay there for a little while, then rotate another 30 degrees, that's a relatively low-use thing; there can be brushed motors that are used and might save space in terms of control system."

Maxon provided six 10-mm, DCX10 brushed DC motors for Ingenuity, used to control the propeller pitch mechanism. They were chosen because brushed motors require less circuitry for controlling, which meant less weight and complexity. "Less wire is better," Randall said, "so in some instances brushed motors will be suitable. Not for propulsion motors, though. Propulsion motors will always be brushless motors."

The Mars Helicopter Ingenuity.

However, the trend lately is the use of greater varieties of motors, specialized depending on the application need. This includes bespoke constructions that rely on longer winds to provide more torque or fewer winds to provide more speed.

Jeremy Laliberte has also seen an increase in overall motor quality. "Better waterproofing, better operating temperatures, I noticed that more of the platforms are now pushing into being able to operate in the rain and sort of better protecting the motors and other electronics and things like that, and more consistency in terms of the quality," he says.

Laliberte said this is especially true for bigger motors for larger (25 kg and above) electric drones, thanks to growth in the EV and electric aviation fields.

But, Laliberte says, the biggest advancements here are actually in motor controllers, with drone makers adding advanced features like handling failed components. "Some of the drone makers have the ability to operate on three motors if you have one fail for some reason," he said. "So you have the kind of automated systems to kind of recover the aircraft, or at least get it on the ground."

Additionally, he says that the increasing availability of electric motor test stands are enabling the development of far more precise motor controls.

Power Sources

While solid-state batteries may provide drastic increases in energy density while also decreasing charge times, zinc-ion batteries may change the way drones are constructed, and hydrogen fuel cells may provide massive flight times and quick refueling, all these technologies are years away from mass adoption. For now, lithium-ion batteries are still the go-to.

Li-ion batteries are nothing new, yet drone flight times continue to increase thanks to ever-improving energy density of these cells along with other efficiency improvements.

"In terms of a modest size mapping project, you can now much more easily carry those out with a multi-rotor instead of having to resort to a fixed-wing drone," Dominique Chabot told us. "That said, you have fixed wings now that can fly for two hours."

The biggest improvements here, according to Jeremy Laliberte, have more to do with increasing battery sophistication and reliability.

"What we've noticed is a trend to batteries that are highly integrated. They're smart, so they have their own charge management systems, they do their own self-discharge for storage. Some of the products we fly, they have heaters built into the batteries for cold weather operations, you know, and improved packaging so they're more robust and durable," Laliberte said. "Most of the major commercial drone manufacturers have quite good integrated systems for sort of giving you all that information about how the batteries are doing. It's not like the old days, just a few years ago, where you would buy your packs at a hobby store and cross your fingers."

Laliberte attributed many of these improvements to increasing demand for advanced batteries in other industries: "As batteries get better for cars, we'll get better from that."

Materials and Construction

As the drone market continues to mature, Jeremy Laliberte sees an increasing sophistication in drone design that, at least in larger craft, will need to rely more heavily on traditional aviation materials, like higher-end composites and aviation-grade alloys.

"I think we'll kind of continue to see the smaller stuff really leading the way with some of the newer technologies," he said. "But the bigger drones, I think, will tend to gravitate to the traditional materials and manufacturing, because there's already all of that certification expertise and knowledge and approval mechanisms for those materials."

These approvals, he says, largely apply to drones greater than 25 kg in mass, at which point the testing and certification in most regions becomes more regimented.

For smaller drones, 3D printing is an increasingly valuable tool. Laliberte says that advanced additive manufacturing techniques mean the lifecycle of these parts has evolved past the prototyping phase. "So, not just mock-ups and demos, but actually parts that are going to go into service and see extended use," he says.

In the future, 4D printing may allow not only for custom-designed parts that provide a static function, but that can actually morph on demand. This could enable a next-generation of hybrid drones offering efficiencies closer to fixed-wing plus capabilities closer to multi-rotor.

However, when it comes to today's frame construction, injection-molded plastics remain common due to low weight and cost, while more structurally significant components continue to rely on carbon fiber due to its high strength, low weight, and low thermal expansion.

Payloads and Capabilities

Sensing, Imaging, and Processing

Imaging remains among the most popular applications for drone use, particularly among recreational, industrial, and research drones. Newer, larger digital sensors capture greater amounts of light at higher resolutions. This not only allows for higher-quality photos, but also provides greater room for software stabilization while still producing acceptably high-resolution output.

"Software, as we say, weighs nothing. So, you know, adding a few lines of code doesn't increase the weight of the aircraft," Jeremy Laliberte said.

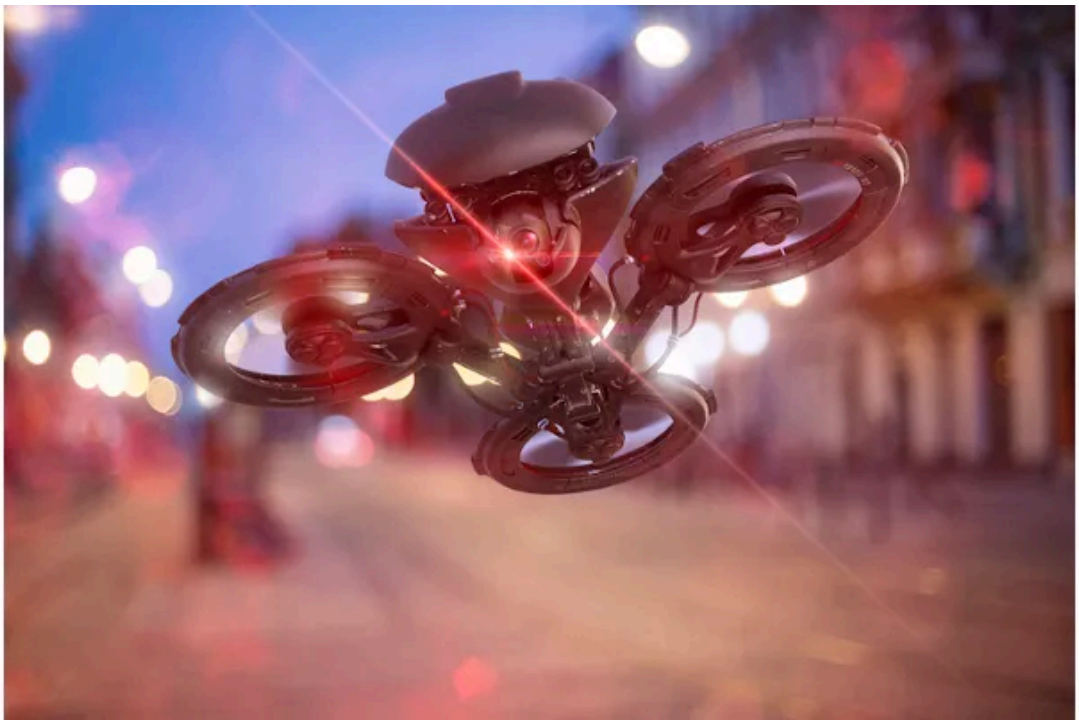
Multispectral cameras offer the ability to capture at various wavelengths, but a new generation of hyperspectral cameras is allowing capture of even more information from a single sensor.

"So a regular run-of-the-mill camera, just a consumer camera, is a three-band camera. It has red, green, and blue, an RGB camera," Dominique Chabot said. "Typically, a multispectral camera will have a minimum of four bands, usually including a near-infrared band is kind of a minimum there ... And you'll have multispectral cameras up to maybe a dozen bands. But, at some point, there's so many bands that we start calling it a hyperspectral camera, and hyperspectral cameras, some of them are hundreds of bands, some of them are maybe as few as a couple-dozen."

Capturing more information means storing more data, and that requires a new level of image processing. Dominique Chabot calls this a "double-edged sword," with researchers often gathering more data than they can effectively parse. "And to go from this raw data to actionable information is a lot of work, always has been a lot of work on the processing and analysis side," he says.

This is a large portion of the sort of work he provides at droneMetrics, applying machine learning and other advanced techniques to finding trends and extracting meaningful information from large volumes of data. "I see that as kind of an extension of the whole drone phenomenon," he said, "because we've got an increasingly efficient platform to collect imagery, but we need to match that with efficient ways to analyze the imagery."

Improvements to machine learning and other aspects of artificial intelligence will be key in keeping up with the ever-increasing volume of data captured by these sensors.



Drones with visible onboard surveillance cameras could patrol city streets.

Surveying

As an extension of imaging, LIDAR is a popular application for survey and research drones, particularly on stable, multi-rotor units, enabling incredibly high-resolution 3D mapping of the drone's surroundings.

However, there's increasing interest in drone applications for synthetic aperture radar, or SAR, which relies on the motion of the platform itself to enable high-detail radar scanning of terrain through sensors that would otherwise only provide low-detail data. Typically used on satellites, SAR systems are being developed for drone use, like NASA's UAVSAR

Though far cheaper, deploying SAR on a drone poses a number of challenges. "Drones, because they're notoriously unstable compared to traditional aerial platforms like a satellite, [which] is very stable, obviously, just following an orbit around the Earth. You don't have to worry about turbulence and vibration," Dominique Chabot said.

Providing that stability requires a concert of systems and sensors, including gyros, accelerometers, and IMUs, all helping to correct the data from the sensors. "Because there's nothing you can do to make a drone more stable," Chabot said, "especially when it starts getting windy and gusty."

Sprayers and Hoppers

As flight times increase, drones can take advantage of larger-capacity hoppers and sprayer, like the aforementioned DJI AGRAS T40, which can run up to 40 kg of liquid for spraying for 50 kg of material for spreading. Use of either volume of payload, however, would result in the weight of the entire package exceeding 25 kg, which in many territories is the threshold that will require additional licensing.

While drone-based sprayers traditionally used flat-fan nozzles, rotary atomizers are increasingly used. This type of nozzle can be tuned to provide even droplet sizes and coverage even amidst uneven flow rates.

The Future: BVLOS and Autonomy

When it comes to applications like drone delivery or automated deployment of fertilizer or pesticides, development is focused on drones flying well outside of the sight of their operators.

"The big focus right now is on what they call beyond visual line of sight, or BVLOS applications," Jeremy Laliberte said. "And this is a global kind of push to get these regulations in place so that operators can, you know, operate drones well beyond the visual line of sight and even in some cases without direct human oversight for the entire flight, like maybe the drones are being monitored by someone a bit like an air traffic controller. But, they're not directly being flown by the operator unless needed."

This sort of operation requires more advanced onboard sensing and identification, operational systems that Laliberte tend to fit within two types. The first category is cooperational, enabling drones to operate and be tracked much more like traditional aircraft with traffic collision avoidance system (TCAS) sensors, including active transponders reporting information like position, speed, and heading.

The second category is non-cooperative, where drones do not actively report their position, much like a modern ultralight aircraft. "So, you need other ways of detecting them," Laliberte said. This includes optical and radar sensors. "Some of those are small enough to go on drones, some of them are not, so this is another area of active research and miniaturizing these systems, making them safe, demonstrating that they have the reliability to meet the regulatory standards."

Those standards themselves are continuing to mature, especially when it comes to drones intended for government and military applications. Concludes Maxon's Jeff Randall: "What the FAA doesn't want is drones falling out of the sky because the motor broke, because a wire bond was weak and it stopped working."

About the Author

Tim Stevens

Tim Stevens is a veteran editor, analyst, and expert in the tech and automotive industries. He helmed *CNET*'s automotive coverage for nine years and acted as vice president of content. Prior to that, Tim served as editor-in-chief at *Engadget* and even led a previous life as an enterprise softwar...

A Not-So-Short History of Unmanned Aerial Vehicles (UAV)

It is easy to see how Unmanned Aerial Vehicles (UAVs), or drones, can be seen as a modern invention.

If we could travel back in time to just ten years ago, the idea of ordering a reliable flying camera online would seem more science fiction than science fact. This is especially true for easily accessible drones with payloads capable of producing thermal, multispectral, and LIDAR-based imagery.

You might be surprised to learn the first UAV dates back to 1783.

Modern technology moves at a somewhat rapid pace. It is easy to forget the building blocks that brought the UAV industry to where it is today. An appreciation for the past achievements that helped to give birth to the modern drone era is essential.

In this piece, we'll review some of the most significant historical events related to the history of drones. In some cases, historical firsts were not specific to the UAV industry; however, they are relevant technological advancements.

When we think of UAVs, hot-air balloons are typically not part of the discussion.

From a technical standpoint, these crafts were the first aircraft to not require a human pilot. Joseph-Michel and Jacques-Étienne Montgolfier hosted the first public demonstration of an unmanned aircraft, a hot-air balloon in Annonay, France.

1849 – The First Military Use of UAVs

Austrian artillery lieutenant Franz von Uchatius invents the balloon bomb. Field Marshall von Radetsky used the balloons to attack Venice, but they were mostly ineffective.

1858 – First Aerial Photograph

Gasper Felix Tournachon takes the first aerial photograph from a hot-air balloon in Paris, France. Unfortunately, the photograph has been lost in history.

1896 – First Camera on a UAV

Alfred Nobel, famous for the invention of dynamite, launches a rocket with a camera on it. Nobel's experiment marks the first time cameras were placed on an unmanned system.

1898 – The First Radio-Controlled Craft

Nikola Tesla displays his radio-controlled boat for a crowd in Madison Square Garden.

The craft could respond to directional signals sent to it by Tesla and could also flash its lights. Some of the audience members thought Tesla was a magician or had the power of telekinesis. Others believed a trained monkey was inside the small boat.

It was a compelling demonstration of what would evolve into radio-controlled aircraft.

map of the German front. The photographs were layout on top of one another and are one of the earliest examples of an orthomosaic.

1917 – First UAV Torpedo the Kettering Bug

Charles Kettering invented the unmanned Kettering Aerial Torpedo, nicknamed the "Bug" in Ohio.

The Bug used a system of pre-set internal pneumatic and electrical controls to stabilize the aircraft. When the Bug reached a pre-determined distance, the engine would stop, wings would detach, and the Bug would fall from the sky.

It carried 180 pounds of explosives.

1935 – The First Modern Drone is Developed

When the Royal Air Force's commenced in 1918, the UK needed effective methods for training pilots.

Target practice was typically accomplished by towing gliders behind crewed aircraft. However, that method failed to provide a realistic simulation for engaging enemy fighters in live combat.

In response, the De Havilland DH.82B Queen Bee aircraft was used a low-cost radio-controlled drone developed for aerial target practice. It is considered by many to be the first modern drone.

1936 – US Drone Program Begins

U.S. Admiral William Harrison Standley witnessed a test flight of the Queen Bee in 1936.

1937 – U.S. Navy Develops a Radio-Controlled UAV Torpedo

The first radio-controlled UAV was the Curtiss N2C-2.

The N2C-2 received its commands from an operator located in a crewed aircraft that flew alongside the Curtiss. While this limited the UAV's effectiveness, it was a significant step in the development of radio-controlled UAV technology.

1941 – Actor Reginald Denny invents the Radio Plane

The Radio Plane was a radio-controlled target plane.

After forming his company, Denny produced target drones for the military and was responsible for numerous drone technology innovations. By the time the Northrop Corporation bought the company in 1952, Denny's company had produced almost 70,000 target drones for the US Army.

1943 – The Beginnings of First-Person View (FPV) Flight

Boeing and the U.S. Airforce developed the BQ-7, which operated on a crude FPV system.

Old bombers were effectively stripped of non-essential equipment and loaded with explosives. A human pilot would fly the aircraft towards the designated target. Once the target was in view, the autopilot was engaged, and the pilot bailed out of the plane. The BQ-7 would then fly to the target on its own.

The BQ-7 was virtually ineffective in war, and the pilots that bailed out had a high rate of death or capture.

1973 – Israel Develops UAVs for Surveillance and Scouting

platforms significantly.

1982 – Battlefield UAVs

The Battle of Jezzine represented the first battle where drones made a considerable difference in the engagement's outcome.

Israel employed their drones to outmaneuver the Syrian Airforce and win the battle with minimal casualties. The legitimacy of UAVs in warfare was established.

1985 – US Significantly Scales Up Drone Production

By the conclusion of the Vietnam War, the U.S. was ready to scale up its drone program.

The successes of Israel's UAV program in the early 1980s made it clear that drones would have a growing role on the battlefields of the future.

1986 – The RQ2 Pioneer Drone is Developed

The U.S. and Israel jointly develop what will become one of the most successful UAV platforms to date.

The system was an upgraded IAI Scout drone and featured significant payload improvements. During the Gulf War, some Iraqi forces even surrendered to a Pioneer UAV.

1991 – UAVs Fly 24/7 During the Gulf War

For the first time in a major conflict, at least one drone was airborne from the conflict's start until its conclusion.

This platform brought weaponized drones to the battlefield like never before. Probably more than any other UAV, the Predator created the public image of drones striking targets around the world.

2006 – UAVs Permitted in US Civilian Airspace for the First Time

Following the devastation caused by Hurricane Katrina, the FAA allowed UAVs to fly in civilian airspace for search & rescue and disaster relief operations.

Predator drones with thermal cameras were able to detect the heat signatures of humans from up to 10,000 feet away. Around this time, the consumer drone industry began to really take shape.

While DJI had yet to become the marketplace giant it is today, companies like Parrot, DJI, 3DR, and many others were looking to take military UAV technology and repurpose it. The potential for industrial and consumer UAV markets was more than enough for many businesses to invest in the technology.

2010 – Parrot Controls a Drone with a Smartphone

At CES, French drone manufacturer Parrot unveiled its AR Drone.

The UAV was a small quadcopter fit for consumer use. An app on a smartphone was all the pilot needed to operate the drone safely.

2013 – DJI Produces the First Phantom Drone

While the company was founded in 2006, the iconic Phantom series was not released until 2013.

This drone began the modern camera-equipped drone craze. Within just a few years, DJI would hold a commanding position in the consumer drone market, with almost

2013 – Major Companies Look to Start Drone Delivery

FedEx, UPS, Amazon, Google, Uber, and countless other delivery companies recognize drone benefits as a delivery platform. Testing of various UAV concepts and work with regulatory agencies around the world begins.

2014 – Use of Drones Rapidly Grows in Industry and with Consumers

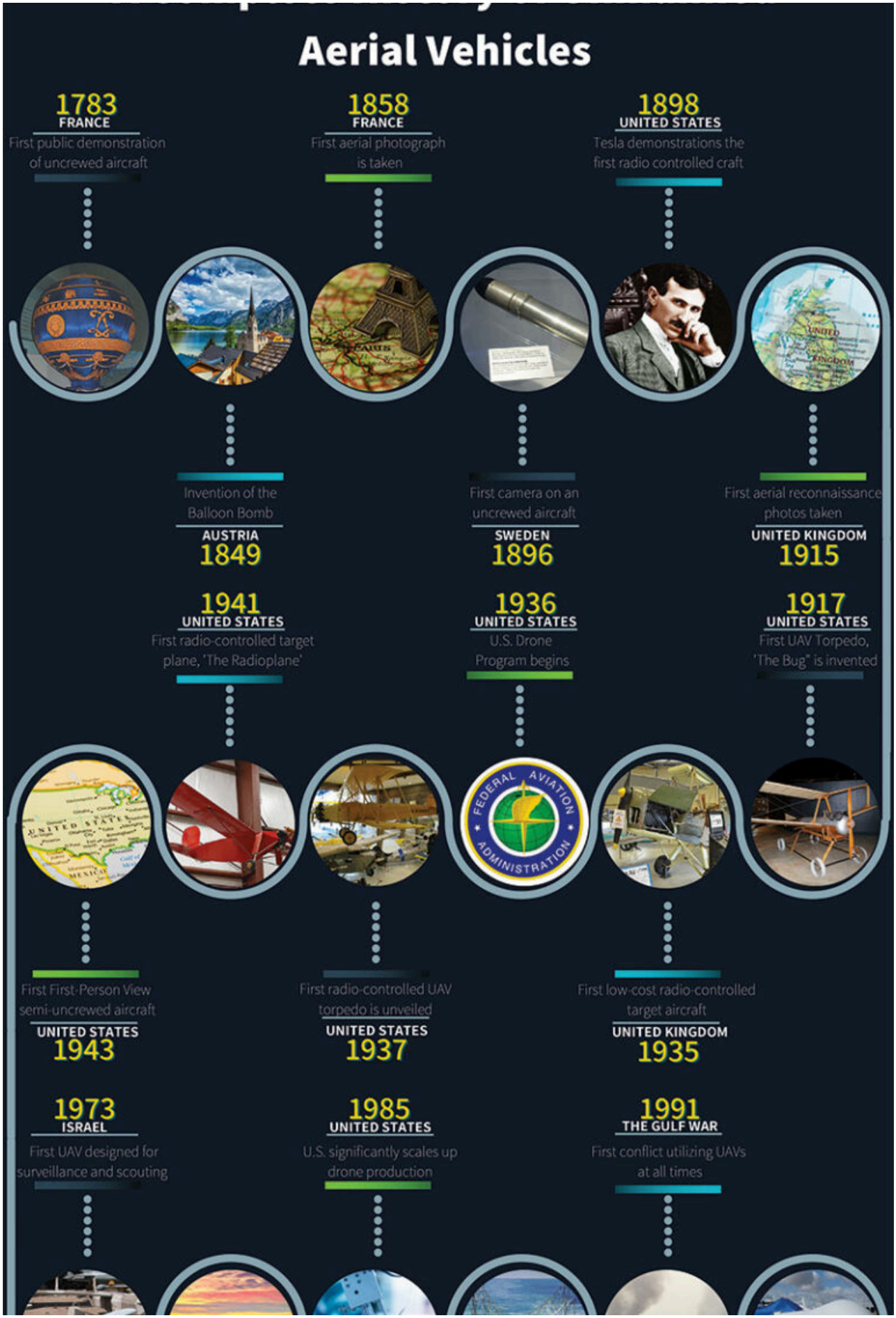
Since 2014, UAVs have continued to expand in capabilities and use cases.

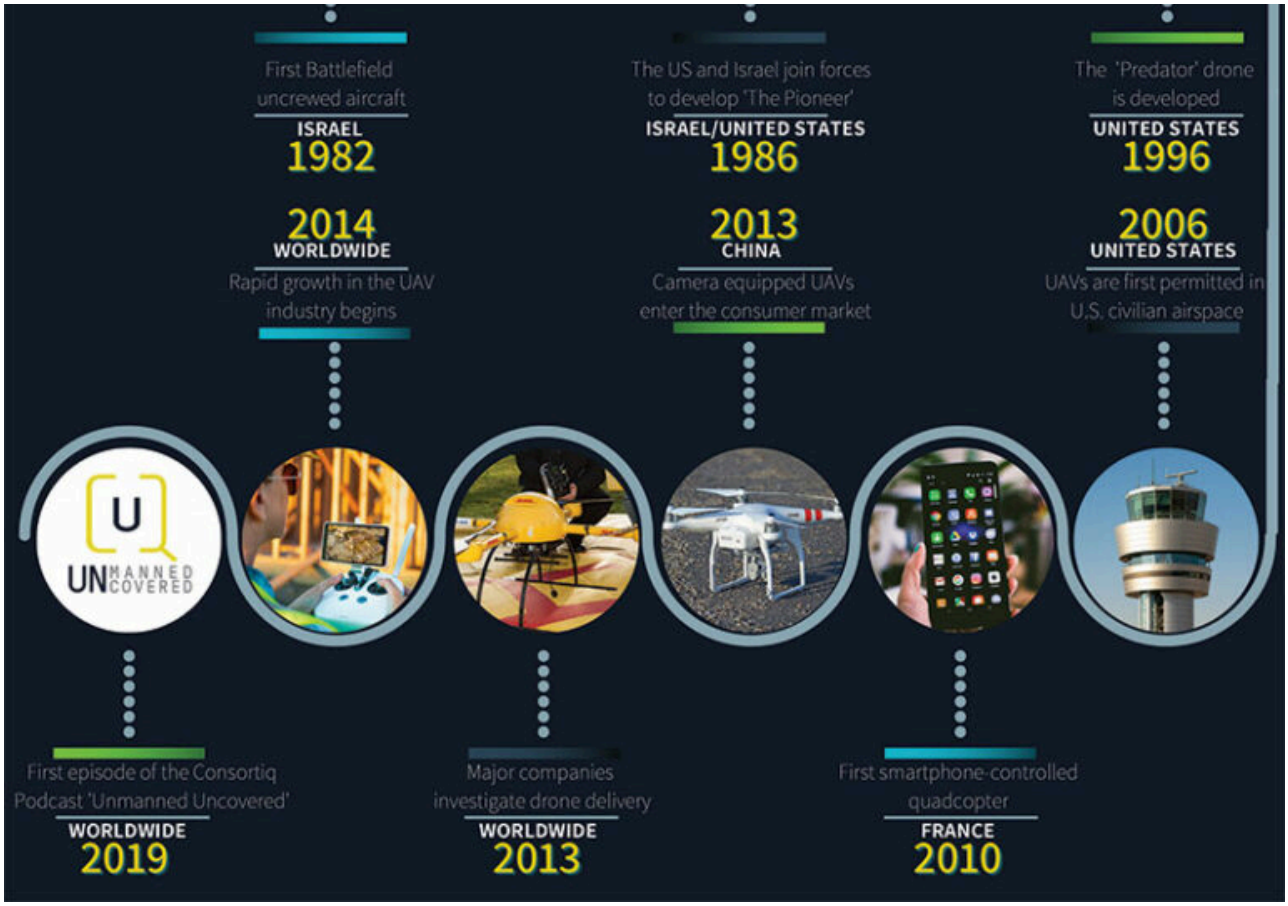
As more industries explore how drones can make their work safer and more cost effective, growth is expected to rapidly surge in the coming years. By 2030, the entire UAV market is set to be worth *$92 billion*.

2020 – Pandemic Alleviation

From quarantine & social distancing enforcement to mass disinfection and medical supply delivery assistance, drones have been a staple during the coronavirus outbreak.

Now, more than ever before, regulations are being adjusted to provide fast-track authorizations for promising use-cases. It's impossible to predict the long-term impact of these developments, but one thing is certain: the pandemic has helped countries around the world imagine the potential that drones hold for society.


Aerial Vehicles
1783
FRANCE
First public demonstration of uncrewed aircraft
1858
FRANCE
First aerial photograph is taken
1898
UNITED STATES
Tesla demonstrations the first radio controlled craft
Invention of the Balloon Bomb
AUSTRIA
1849
First camera on an uncrewed aircraft
SWEDEN
1896
First aerial reconnaissance photos taken
UNITED KINGDOM
1915
1941
UNITED STATES
First radio-controlled target plane, 'The Radioplane'
1936
UNITED STATES
U.S. Drone Program begins
1917
UNITED STATES
First UAV Torpedo, 'The Bug" is invented
FEDERAL AVIATION ADMINISTRATION
First First-Person View semi-uncrewed aircraft
UNITED STATES
1943
First radio-controlled UAV torpedo is unveiled
UNITED STATES
1937
First low-cost radio-controlled target aircraft
UNITED KINGDOM
1935
1973
ISRAEL
First UAV designed for surveillance and scouting
1985
UNITED STATES
U.S. significantly scales up drone production
1991
THE GULF WAR
First conflict utilizing UAVs at all times



What's Next?

If you are looking to explore what UAV technology can do for your organization, speak with the experts at Consortiq. The historical achievements of the UAV industry can help shape your future successes.

In the past few years alone, drones have been used to monitor penguins in Antarctica, assist farmers with crop output, take surveys of infrastructure, and even perform critical search-and-rescue missions for scores of emergency responders.

Sure, the technology seems new, but it's certainly not unproven. And, as you've seen in this article, it's been around for a very, very long time.

Many businesses are using drones to improve operations. Because with drones, there's always a better way to do things.

looking for training as a drone pilot?

Whether you're looking to outsource your work or learn how to do it yourself, just complete the form below and we'll help you get started!

Isn't it time you found a better way?

David Daly - Contributing Author

David Daly, is an award-winning photographer/writer and licensed (FAA) Commercial sUAS pilot. A graduate of the United States Naval Academy, David is a former Marine Corps officer with a BS in Oceanography and has earned his MBA from the University of Redlands. David has worked for Fortune 100 companies and has a background in aerospace, construction, military/defense, real estate, and technology.

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